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Aggregate and Soil Proficiency Sample Testing Program for 2014

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Abstract	The Materials Engineering and Research Office, Soils and Aggregates Section, conducts a proficiency sample testing program for aggregate and soil materials each year to provide a means for participating laboratories to see if they are performing satisfactorily. We also conduct a sample testing program for the tests related to Superpave consensus properties of aggregates. This is conducted along with our annual Aggregate and Soil Proficiency Sample Testing Program. The laboratories are asked to perform a number of different tests on pairs of samples that have been prepared and randomly selected at the MTO Laboratory. The samples are delivered to the participating laboratories starting in June, and they report their results starting in early August. A preliminary report issued in the second week of September allows the laboratories to examine their procedures or equipment and correct any problems that may have occurred. This year, two hundred and thirty-four participants from the private and public sector participated in the Aggregate and Soil Proficiency Sample Testing Program. Fifty-nine laboratories from the private sector and MTO Downsview laboratory reported results for all four of the Superpave consensus property tests. Results of the aggregate and soil tests from the 2014 program are found to be consistent with the results reported in the last three years, but, in majority of the tests, the multi-laboratory variations show noticeable improvements over the ASTM, AASHTO or MTO precision estimates where available. Although there is improvement in the multi-laboratory variations, strong laboratory biases still remain in four of the aggregate tests, two of the Superpave tests procedures and all of the soil tests. Sieve analysis results also show that the sample preparation method employed is very effective and capable of producing a uniform and nearly identical material at reasonable cost. We expect that the mandatory Laboratory Quality System implemented by CCIL and their lab inspection process will bring about improvements in multi-laboratory variations.
Key Words	Aggregate, consensus property, correlation, laboratory, proficiency testing, soil, Superpave
Distribution	Unrestricted technical audience.

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Executive Summary

The Soils and Aggregates Section of the Materials Engineering and Research Office runs an annual proficiency sample testing program for aggregate and soil tests. This program provides a means for participating laboratories to see if they are performing satisfactorily. The laboratories are asked to perform a number of different tests on randomly selected pairs of samples that have been prepared by the MTO Soils and Aggregates Laboratory. The samples are delivered to the participating laboratories starting in June. The laboratories are required to report their results by the second week of August. A preliminary report issued in the second week of September gives feedback to the participants while they are still operational in the current year. This allows them to examine their procedures or equipment and correct any problems that may exist. A final report is issued after full analysis of the data has been completed.

This is the final report for the 2014 MTO Aggregate and Soil Proficiency Sample Testing and the Superpave Aggregate Consensus Property Testing Programs. Proficiency test samples in duplicates were shipped to two hundred and forty-one participants from the private and public sector laboratories. Two hundred and thirty-four of the participants that requested samples submitted test results in 2014. Of these, one hundred and forty-five were aggregate producers' and road builders' Quality Control (QC) laboratories. The remainder were engineering testing consultants' and owners' laboratories. Participation in this program is mandatory for laboratories conducting quality assurance (QA) and referee testing work for MTO contracts. However, participation is optional for laboratories that do quality control (QC) testing for contractors. In general, contractor and supplier laboratories are conducting particle size analysis, wash pass 75 μm, percent crushed particles, percent asphalt coated particles, percent flat and elongated and density tests for granular base and sub-base aggregates.

In 2014, sixty-six laboratories reported results for one or more of the tests related to Superpave aggregate consensus properties. The laboratories that participate in this program conduct uncompacted void content of fine aggregate, sand equivalent value of fine aggregate, percent of fractured particles in coarse aggregate, and percent flat particles, elongated particles, or flat and elongated particles in coarse aggregate tests, in accordance with the ASTM/AASHTO test methods.

Reports to individual laboratories contain ratings for each test method, which are based on the standardized deviate for that test (i.e. a rating of 5 for data within 1.0 standard deviation of the mean, a rating of 0 for data 3.0 or more standard deviations from the mean). Ratings of each test method are also used to calculate an overall laboratory rating for each category of tests. This rating system has acted as an incentive for laboratories to improve their performance. The rating is also used as a guide by MTO to select laboratories for its quality assurance testing and for qualifying referee laboratories.

Results of the aggregate and soil tests from the 2014 program are found to be consistent with the results from previous years and, in majority of these tests, the multi-laboratory variations show noticeable improvements over the precision estimates published by AASHTO, MTO, or ASTM. Particularly, wash pass 75 μm, sieve analysis of coarse and fine aggregates, relative density and absorption of both coarse and fine, magnesium sulphate soundness of coarse aggregate, percent crushed particles of coarse aggregate, percent flat and elongated particles of coarse aggregate, freeze-thaw loss of coarse aggregate, Micro-Deval abrasion of fine aggregates, and moisture density relationship (one-point Proctor) show improvements over the precision estimates published by ASTM or MTO and the results reported in the past three years. Although the precision of most of the aggregate test methods compares favourably in relation to the results of previous studies and the precision estimates where available, strong laboratory biases still remain in the following test methods: relative density and absorption of fine aggregate (LS-605), magnesium sulphate soundness of coarse aggregate (LS-606), freeze-thaw loss of coarse aggregate (LS-614), and Micro-Deval abrasion of fine aggregates (LS-619). The variations in soil test results show improvement and are lower than the values reported in the previous three years of study, but the scatter plots of all three soil tests show a strong laboratory bias.

The results of Superpave consensus property tests from the 2014 program also compare favourably with the past performance of the laboratories. The multi-laboratory variations of sand equivalent value of fine aggregate (ASTM D 2419), percent flat and elongated particles of coarse aggregate (D 4791), and percent fractured particles of coarse aggregate (D 5821) tests show noticeable improvements over the precision estimates published by ASTM and the values reported in the past three years. Although, there is noticeable improvement in the performance of the laboratories, the scatter diagrams for ASTM D 2419 and D 4791 show strong laboratory biases.

The Soils and Aggregates Section continues to carry out the inspection of laboratories providing soil testing services to the ministry. This inspection is being done at the request of laboratories. The laboratories that are inspected and accepted by MTO must request a re-inspection if a technician who demonstrated the tests during inspection is no longer available or there has been any change in the equipment. To date, fifty-four laboratories have been inspected. Thirty-five of these laboratories are on the MTO Vendors List to do testing of soils for MTO work.

1. Introduction

This is the final report of the 2014 inter-laboratory testing program organized by MTO for aggregate and soil test methods. It is primarily intended to provide a means for laboratories used by MTO to see if they are performing satisfactorily and to qualify these laboratories to perform quality assurance and referee testing for MTO contracts[1]. The design of the testing program is based on procedures for determining the precision and variability of test methods. Interested readers should refer to ASTM C670[2], C802[3], E177[4], and E178[5] for further information on inter-laboratory testing programs.

Proficiency test samples were distributed to two hundred and forty-one participants from the private and public sector laboratories. A total of two hundred and thirty-four participants reported results for the Aggregate and Soil Proficiency Sample Testing Program conducted in the summer of 2014. The participants were also asked to submit results for Superpave aggregate consensus property tests, if they were equipped to perform those tests. Fifty-nine laboratories submitted results for all of the tests related to the consensus properties. Participants in both testing programs included the MTO laboratory in Downsview, the remainder being from the private sector (contractors, aggregate producers, and engineering consultants), and municipalities. Samples were delivered to laboratories in early June. A preliminary report was issued to the participants in mid-September.

Reports to individual laboratories contain ratings for each test method, which are based on the standardized deviate for that test (i.e. a rating of 5 for data within 1.0 standard deviation of the mean, a rating of 0 for data 3.0 or more standard deviations from the mean). Ratings of each test method are also used to calculate an overall laboratory rating. This rating system has acted as an incentive for laboratories to improve their performance.

The computer program that was developed by MTO to handle the computation and presentation of test data has two statistical methods, namely the Critical Value Method recommended in Section 4 of ASTM E178 and the Iterative (Jack-knife) Technique recommended by Manchester (1979), to detect outlying observations or outliers in a set of data. For details of the program, refer to the User's Manual (report MERO-013) by Vasavithasan and Rutter, 2004. A number of statistical methods are available to test the hypothesis that the suspect observations are not outliers. MTO study often follows the Critical Value Method to remove outliers. However, the Jack-knife method is used where the strict application of the critical value method tends to include extraneous results that may not stand the best chance of representing the testing performed in conformance with each of the test methods. The critical value method and iterative techniques are based on two

1 Laboratories must also be inspected and recognized by the Canadian Council of Independent Laboratories (CCIL).
2 ASTM C670 Practice for Preparing Precision and Bias Statements for Test Methods of Construction Materials.
3 ASTM C802 Practice for Conducting an Inter-laboratory Test Program to Determine the Precision of Test Methods of Construction Materials.
4 ASTM E177 Practice for Use of Terms Precision and Bias in ASTM Test Methods.
5 ASTM E178 Practice for Dealing with Outlying Observations.

different statistical approaches. As a result, the confidence intervals yielded by these two methods differ widely depending on the number of observations (number of laboratories participating in a particular test method) and the distribution of data. In the case of Iterative Technique, test results that fall beyond 2.8 times the standard deviation from the mean may be identified as outliers depending on the number of observations and distribution of data.

The critical value used in this study is that value of the sample criterion, which would be exceeded by chance with some specified probability (significance level) on the assumption that all observations in the sample come from the same normally distributed population. The critical values provided in ASTM E178, Table 1 are limited to 147 observations, but over 225 laboratories participate in our annual testing program. The critical values that are being used for the MTO study were calculated at five percent significance level (Grubbs' test) based on Grubbs' (1969 and 1972) recommendations for identifying outliers.

2. Test Results

2.1 TABLE OF TEST RESULTS

Each participant receives an individual summary of results for their laboratory. An example of a typical report is shown in Tables 1, 2, 3, and 4. Each Table of Results identifies the laboratory by number and compares the laboratory's data with the means obtained after statistical analysis of the data received from all laboratories. The identity of the laboratories is kept confidential.

Column 1 gives the test method as designated in the MTO Laboratory Testing Manual.

Columns 2 and 3 show the test data submitted by the laboratory for a pair of samples.

Columns 4 and 5 show the mean (average) test value for each sample after removal of outliers and/or invalid test results from the data set for all laboratories performing the test.

Columns 6 and 7 list the standardized deviate for each test result. The standardized deviate is used to show how the individual test results compare to the mean. It is obtained by subtracting the mean of all data ($\overline{X}$) from the actual test result reported by the laboratory (X_i) and dividing by the standard deviation (s). That is:

$$\text{Standardized Deviate} = \frac{\left(X_i - \overline{X}\right)}{s}$$

If the test result is less than the mean, the standardized deviate is negative and, if the test result is greater than the mean, the standardized deviate is positive. In brief, the standardized deviate tells us how many standard deviations the test result is away from the mean.

Columns 8 and 9 list the test method ratings, which are similar to the standardized deviate, but are in a simple numeric form. Ratings are determined as follows:

Rating 5 - data within 1.0 standard deviation of the mean.
Rating 4 - data within 1.5 standard deviations of the mean.
Rating 3 - data within 2.0 standard deviations of the mean.
Rating 2 - data within 2.5 standard deviations of the mean.
Rating 1 - data within 3.0 standard deviations of the mean.
Rating 0 - data 3.0 or more standard deviations from the mean
or data considered to be outlying by other methods.

A negative sign simply indicates a result that is smaller than the mean. If one of the paired test results for a given test is excluded based on the outlier criteria, the other test result is still subjected to the statistical analysis and is only excluded if it also fails to meet the criteria.

An outlying observation is one that appears to deviate markedly from the sample population. It may be merely an extreme manifestation of the random variability inherent in the data, or may be the result of gross deviation from the prescribed experimental procedure, calculation

errors, or errors in reporting data. The outlier criteria employed for exclusion of test results from the analysis will depend on the distribution of data and the number of participants in a test. The iterative technique is one of the methods employed in this study for the selection of outliers, and is used where the strict application of critical value method tends to include the data that does not belong to the population. In the critical value method, the standardized deviate of a lab result is compared with the critical value corresponding to the number of participants in that particular test, for rejecting an outlier. The critical value is greater than 3 when the number of participants in a particular test method is 30 or more. For this reason, results with more than 3 standardized deviates may not have been identified as an outlier unless it is higher than the critical value, but a zero rating is nevertheless assigned for the test result in question. For example, if the computed standardized deviate for a lab result is 3.236 and the critical value corresponding to the number of participants in that particular test is 3.427, the lab will not be identified as an outlier but a zero rating will be assigned.

Significance need not necessarily be attached to a single low rating. However, a continuing tendency to get low ratings on several pairs of samples or on a series of tests from one procedure (e.g. sieve analysis) should lead a laboratory to re-examine its equipment and test procedure. A laboratory that reports data for a specific test consistently lower or higher than the mean over a number of test periods also needs to re-examine their test procedure, because this is evidence of a systematic bias in how the laboratory conducts the procedure. Any computer program that is used by a laboratory to calculate test results should be verified as part of this examination.

2.2 SCATTER DIAGRAMS

Youden scatter diagrams are supplied with this report (see Appendices D1 and D2). A laboratory can locate itself on the diagrams by plotting its test value for the first sample (1.14) on the horizontal axis, against its test value for the second sample (2.14) on the vertical axis. The horizontal and vertical axes are of equal length and are scaled to give the most informative display of the plotted points. In some cases, the outlying results plot outside the boundaries of the diagram. If the results from two or more laboratories happen to coincide, a single point is plotted.

Below each scatter diagram, the test number and title are given, followed by a table of statistical calculations for both samples. Here the mean, median, and standard deviation for each sample are given. The number of laboratories reporting valid data and the laboratories eliminated by statistical analysis are also listed.

The vertical and horizontal crosshairs on the plots represent the mean values for all the valid results on the first sample (1.14) and the second sample (2.14), respectively. These lines divide the diagram into four quadrants, numbered 1 through 4, beginning in the upper right-hand quadrant and continuing clockwise. In an ideal situation where only random errors occur, the points are expected to be equally numerous in all quadrants and will form a circular distribution. This follows because plus and minus errors should be equally likely. Often, however, the points tend to concentrate in quadrants 1 and 3 on the diagram. This occurs because laboratories tend to get high or low results on both samples. This gives evidence of individual laboratory biases. As the tendency to laboratory bias increases, the

departure from the expected circular distribution of points towards a linear distribution from quadrant 1 to 3 occurs. Such a distribution of points indicates systematic variation. Figure 1 gives examples of scatter diagrams.

Table 1. Summary of Results for Laboratory 47

TEST RESULTS FOR LABORATORY NUMBER 47			DATE PREPARED: October 24, 2014					
COARSE AGGREGATE REFERENCE SAMPLES 1.14 & 2.14								
TEST METHOD	LABORATORY DATA		MEAN OF LABORATORIES		STANDARDIZED DEVIATE		LAB RATING	
	1.14	2.14	1	2	1	2	1	2
LS-601 Wash Pass 75 µm (Coarse Agg.)	0.840	1.150	1.002	1.147	-1.006	0.017	-4	5
LS-602 – Coarse Aggregate Percent Passing 19.0 mm Percent Passing 16.0 mm Percent Passing 13.2 mm Percent Passing 9.5 mm Percent Passing 4.75 mm	 97.500 89.500 80.300 65.700 47.530	 97.800 91.400 81.900 68.000 50.100	 96.705 88.566 79.496 63.395 45.301	 96.945 89.178 80.610 65.088 46.912	 1.179 0.866 0.617 1.707 1.735	 1.434 2.148 0.886 1.736 2.074	 4 5 5 3 3	 4 2 5 3 2
LS-603 Los Angeles Abrasion, %	26.900	26.400	26.373	26.545	0.398	-0.126	5	-5
LS-606 – Coarse Aggregate $MgSO_4$ Soundness Loss, %	7.000	6.300	4.851	4.692	1.490	1.648	4	3
LS-606 – Fine Aggregate $MgSO_4$ Soundness Loss, %								
LS-607 Percent Crushed Particles	79.800	79.800	76.418	76.415	1.049	1.012	4	4
LS-608 % Flat & Elongated Particles	2.900	4.100	4.888	4.533	-1.098	-0.247	-4	-5
LS-609 Petrographic Number (Concrete)	116.20	114.00	112.85	112.01	0.636	0.367	5	5
LS-613 Total % of Insoluble Residue Insoluble Residue Retained 75µm	 24.400 **23.200**	 29.000 27.800	 40.188 **39.027**	 41.100 36.815	 -1.759 ***-6.705**	 -1.791 -2.277	 -3 **0**	 -3 -2
LS-614 Freeze-Thaw Loss, %	9.600	9.600	8.714	8.640	0.426	0.514	5	5

Blank spaces represent not tested.
Bold and Underline * - Calculation considered outlier
∩ - Outliers by Manual Deletion

Table 2. Summary of Results for Laboratory 47

TEST RESULTS FOR LABORATORY NUMBER 47			DATE PREPARED: October 24, 2014					
FINE AGGREGATE REFERENCE SAMPLES 1.14 & 2.14								
TEST METHOD	LABORATORY DATA		MEAN OF LABORATORIES		STANDARDIZED DEVIATE		LAB RATING	
	1.14	2.14	1	2	1	2	1	2
LS-618 Micro-Deval Abrasion Loss (CA)	13.200	11.500	11.854	11.921	2.090	-0.612	2	- 5
LS-620 Accelerated Mortar Bar (14 Days)								
LS-623 Maximum Wet Density (g/cm^3) Maximum Dry Density (g/cm^3) Optimum Moisture, %	2.384 2.220 7.400	2.401 2.240 7.200	2.365 2.200 7.573	2.367 2.204 7.550	0.663 0.652 -0.739	1.254 1.354 -1.367	5 5 -5	4 4 -4
LS-604 – Coarse Aggregate Relative Density (O.D.) Absorption	 2.669 0.710	 2.665 0.680	 2.666 0.734	 2.665 0.740	 0.469 -0.309	 -0.037 -0.762	 5 -5	 -5 -5
LS-621 Asphalt Coated Particles, %	45.000	42.500	45.716	39.409	-0.142	0.636	-5	5

Blank spaces represent not tested.
Bold and Underline * - Calculation considered outlier
∩ - Outliers by Manual Deletion

Table 3. Summary of Results for Laboratory 47

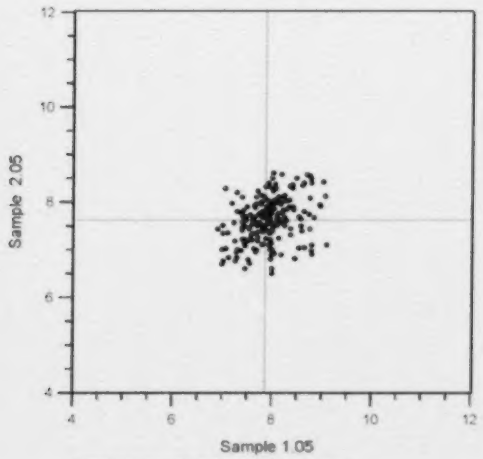
TEST RESULTS FOR LABORATORY NUMBER 47			DATE PREPARED: October 24, 2014					
FINE AGGREGATE REFERENCE SAMPLES 3.14 & 4.14								
TEST METHOD	LABORATORY DATA		MEAN OF LABORATORIES		STANDARDIZED DEVIATE		LAB RATING	
	3.14	4.14	3	4	3	4	3	4
LS-605 – Fine Aggregate								
Relative Density (O.D.)	2.680	2.685	2.666	2.665	1.484	1.792	4	3
Absorption	0.580	0.430	0.709	0.719	-1.070	-2.266	-4	-2
LS-619 – Fine Aggregate								
Micro-Deval Abrasion	10.800	10.900	10.271	10.415	0.687	0.548	5	5
LS-602 – Fine Aggregate								
Percent Passing 2.36 mm	**40.300**	40.000	**35.334**	36.639	***3.367**	1.859	**0**	3
Percent Passing 1.18 mm	27.800	30.500	26.595	27.666	0.768	1.581	5	3
Percent Passing 600 µm	18.500	20.000	17.940	18.570	0.450	0.984	5	5
Percent Passing 300 µm	10.700	11.200	10.206	10.548	0.635	0.709	5	5
Percent Passing 150 µm	6.400	6.600	6.191	6.324	0.433	0.594	5	5
Percent Passing 75 µm	4.680	4.830	4.360	4.429	0.918	1.037	5	4

Blank spaces represent not tested.
Bold and Underline * - Calculation considered outlier
∩ - Outliers by Manual Deletion

Table 4. Summary of Results for Laboratory 47

TEST RESULTS FOR LABORATORY NUMBER 47			DATE PREPARED: October 24, 2014					
SOILS REFERENCE SAMPLES 5.14 & 6.14								
TEST METHOD	LABORATORY DATA		MEAN OF LABORATORIES		STANDARDIZED DEVIATE		LAB RATING	
	5.14	6.14	1	2	1	2	1	2
LS-702 – Sieve Analysis of Soil								
Percent Passing 2.00 mm	99.800	99.800	99.875	99.840	-0.606	-0.268		
Percent Passing 425 µm	98.000	98.000	97.575	97.616	1.202	1.122	4	4
Percent Passing 75 µm	93.500	93.200	93.002	93.097	1.209	0.242	4	5
Percent Passing 20 µm	84.100	83.800	85.452	85.951	-0.500	-0.793	-5	-5
Percent Passing 5 µm	75.200	76.600	76.159	76.946	-0.317	-0.116	-5	-5
Percent Passing 2 µm	64.800	65.800	65.525	66.153	-0.229	-0.108	-5	-5
LS-703								
Liquid Limit, %	51.100	53.700	48.075	48.317	1.565	2.428	3	2
LS-704								
Plastic Limit, %	22.500	22.800	21.243	21.169	0.758	1.005	5	4
Plasticity Index, %	28.600	30.900	26.767	27.028	0.938	1.684	5	3
LS-705								
Specific Gravity of Soil	2.747	2.749	2.755	2.758	-0.277	-0.289	-5	-5
AGGREGATE CONSENSUS PROPERTIES								
Uncompacted Void Content	43.800	43.700	42.852	42.807	1.568	1.847	3	3
Sand Equivalent Value	70.100	67.500	66.325	66.097	0.763	0.284	5	5
Percent Fractured Particles	80.500	80.900	78.997	79.177	0.663	0.692	5	5
% Flat & Elongated Particles	0.600	0.800	1.120	1.126	-0.852	-0.500	-5	-5

Blank spaces represent not tested.
Bold and Underline * - Calculation considered outlier
∩ - Outliers by Manual Deletion

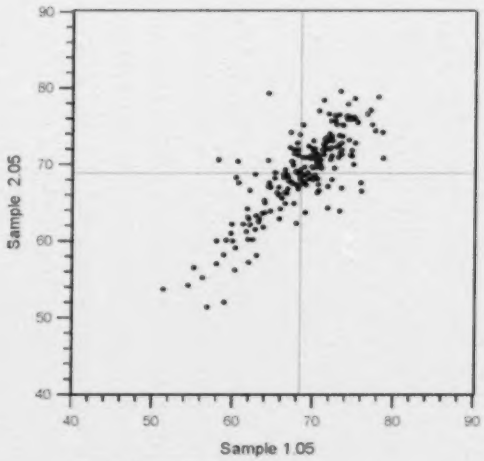


Test 25: Percent Passing the 75 um Sieve

	Mat 1	Mat 2
Mean	7.930	7.630
Median	7.800	7.500
Std Dev	0.460	0.470
n = 203		

Labs Eliminated: 447, 497, 452, 518

Scatter diagram for a test showing random variation with little laboratory bias

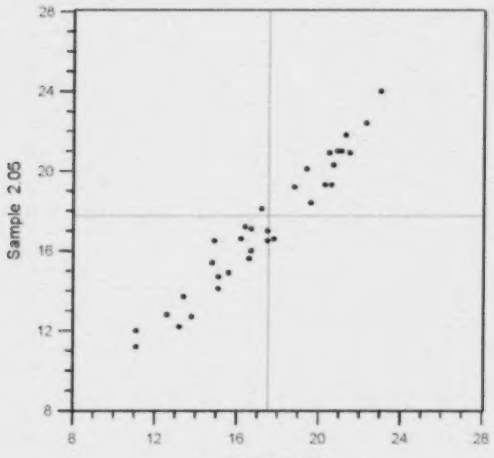


Test 12: Percent Crushed Particles

	Mat 1	Mat 2
Mean	68.491	68.905
Median	68.300	64.500
Std Dev	5.054	5.402
n = 201		

Labs Eliminated: 345, 350, 436, 460

Scatter diagram for a test showing a combination of random variation and laboratory bias for some laboratories

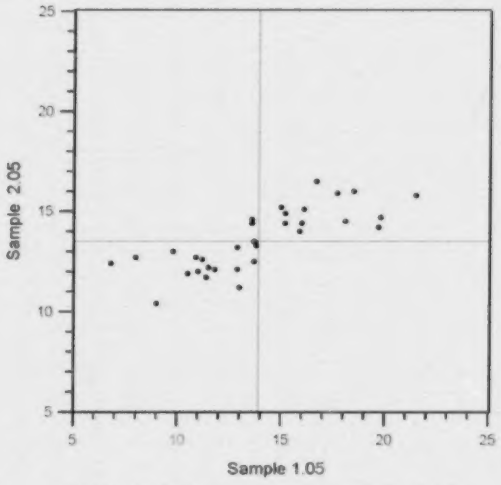


Test 29: MgSO4 Soundness (Fine Aggregate), % Loss

	Mat 1	Mat 2
Mean	17.370	17.258
Median	15.800	15.600
Std Dev	3.276	3.325
n = 32		

Lab Eliminated: None

Scatter diagram for a test showing pronounced between laboratory bias and equal variation for each material



Test 11: MgSO4 Soundness (Coarse Aggregate), % Loss

	Mat 1	Mat 2
Mean	13.890	13.570
Median	12.900	13.600
Std Dev	3.533	1.541
n = 31		

Lab Eliminated: None

Scatter diagram for a test with pronounced between laboratory bias but unequal variation for each material

Figure 1. Examples of Scatter Diagrams

2.3 OUTLIERS

In dealing with suspected outlying observations or 'outliers', our purpose is to remove those observations that do not belong to the sample population and to provide some statistical criteria for doing so. There are a number of ways to do this. In most of these, as ASTM E178 states, 'the doubtful observation is included in the calculation of the numerical criterion (or statistic), which is then compared with a critical value based on the theory of random sampling to determine whether the doubtful observation is to be retained or rejected.' The critical value is that value of the sample criterion that would be exceeded by chance with some specified (small) probability on the assumption that all observations did indeed constitute a random sample from a common system of causes, a single parent population, distribution, or universe.

The MTO study often follows the criteria recommended for single samples in Section 4 of ASTM E178 for rejecting the doubtful observations at the ninety-five percent confidence level. The critical value method is based on the assumption of normality, and the critical values are calculated using Student's T distribution. The assumption in this method is that all of the observations come from the same normal population. The doubtful observation is included in the calculation of mean and standard deviation of the population. Then the critical value, T_n, for that observation, n, in question is calculated and compared with the critical value based on the theory of random sampling. The doubtful observation is rejected if T_n is higher than the critical value for the five percent significance level. The outlier is removed from the data set and the iterations are continued until no outliers are detected, and a revised mean and standard deviation are calculated after deleting the outlier. The ratings of the laboratories are determined based on the revised mean, standard deviation, and standardized deviate.

In some cases, the strict application of the critical value method tends to include laboratories in the population that report extraneous results. These results may not represent testing performed in conformance with the test method. In those cases, the application of the iterative technique (Manchester[6]) is used. The Constant C in the iterative technique is computed using Fisher's F distribution, and it depends on the number of participating laboratories in a particular test. In this technique, an outlying observation is rejected based on a statistical criterion, but the confidence interval may vary depending on the number of participants and the distribution of sample population.

In the iterative technique, after screening the test results for any errors, the doubtful test result is included in the calculation of mean and standard deviation of the data set. The absolute residual values (actual test result minus the mean) are then computed and test result farthest from the mean by a unit of Cs (standard deviation, s, multiplied by a constant C) is identified as an outlier. One outlier at a time is identified and rejected in a manner similar to that of critical value method.

6 The Development of an Interlaboratory Testing Program for Construction Aggregates, by L. Manchester, Ministry of Transportation, Ontario, Engineering Materials Office Report EM-33, Downsview, December, 1979.

Three of the test methods included in this proficiency sample testing program requires reporting of control sample results to demonstrate that the testing process of the laboratory is in control. The laboratories that report control sample results outside the range of values established for the material are identified during the screening of test results for any errors or deviations. These laboratories are manually removed from the data set during the analysis and considered as outliers.

3. Discussion

The following discussion contains general and test-specific comments for the 2014 test period. Where ASTM, AASHTO or MTO precision statements are published for a given test, an attempt has been made to compare these with the statistics for this period.

A discussion of statistical techniques is presented in the Glossary of Terms, found in Appendix A.

3.1 NOTES ON MATERIAL SOURCES

Materials used in this test period were as follows:

- Coarse and fine aggregate tests, including Sieve Analysis, Magnesium Sulphate Soundness (coarse), Percent Crushed Particles, Moisture Density Relationship, Relative Density and Absorption (fine), Micro-Deval Abrasion Loss (fine), Uncompacted Void Content, Sand Equivalent Value, and Percent Fractured Particles – Granular A (OPSS 1010) from Stewart Pit No. 5, Rugby, Orillia (MTO MAIDB No. O11-144).
- Coarse aggregate tests, including Wash Pass 75 µm, Percent Flat and Elongated Particles, Petrographic Analysis (coarse), Relative Density and Absorption (coarse), Los Angeles Abrasion, Micro-Deval Abrasion Loss (coarse), Freeze-Thaw Loss, and Percent Flat, Elongated, or Flat and Elongated Particles – clear-stone (OPSS 1003) from Stewart Pit No. 5, Rugby, Orillia (MTO MAIDB No. O11-144).
- Fine Aggregate Petrographic Examination - sand from Stewart Pit No. 5, Rugby, Orillia (MTO MAIDB No. O11-144).
- Soil tests – Waterford Law Quarry, Port Colbourne, (MTO MAIDB No. S06-051).

3.2 NOTES ON SAMPLE PREPARATION

The material processed for the coarse and fine aggregate tests conforms approximately to the gradation requirements of Granular A. Bulk samples were prepared using a large spinning riffler, developed and built by staff at the MTO Downsview Laboratory (refer to Figures 2 and 3 of Report MI-179, February 2000). The use of a spinning riffler ensures that, as far as possible, each sample is identical to every other sample. It has been found that this is the best technique for minimizing sample bias. A bobcat loader was used to fill an aggregate bin from the stockpile and the material was fed along a conveyor belt to fill 33 identical bags (fitted with funnels) on a spinning turntable. It was found that about 25 revolutions of the turntable were required to fill each bucket to 27 ± 2 kg of Granular A. This resulted in more homogeneity of the samples than would normally be the case using other techniques. In total, six hundred and fifty 27 ± 2 kg samples were prepared for the tests on Granular A, and randomized for distribution to participating laboratories. The participants were responsible for the preparation of their own fine aggregate samples (3.14 and 4.14) from the two bags of Granular A supplied.

In addition to Granular A, additional samples consisting of material with approximately 97.5% retained on 4.75 mm sieve was also supplied for tests that require coarse aggregates. The number of revolutions of the turntable required for coarse aggregate to fill each bucket to approximately 28 ± 2 kg was found to be about 26 revolutions of the turntable. In total, six hundred and fifty 28 ± 2 kg samples were prepared for the coarse aggregate tests, and randomized for distribution to participating laboratories.

Soil material was air-dried, processed to pass through a 2.0 mm sieve using a Fritsch Soil Mill Pulveriser, and placed in 20 kg buckets. Individual scoops were collected from each bucket and placed in a separate container. The material from the container was then transferred to the hopper of a small spinning riffle splitter. The hopper of the spinning riffler used is capable of filling 24 identical 2 kg containers per run. This method was used to create uniform 20 kg buckets. The proficiency test material was then prepared by obtaining representative samples from a 20 kg bucket. The material collected from the 20 kg bucket was then transferred to the hopper of the small spinning riffler and the 500 g proficiency test samples were prepared. The samples were then randomized for distribution to participating laboratories.

3.3 NOTES ON INDIVIDUAL TESTS

For each test, comments have been made pertaining to the variation illustrated by the associated scatter diagrams shown in Appendices D1 and D2. The technique used to test for outliers is stated and, where possible, reasons for the outlying observations are offered. It is important to keep in mind that there are many variables influencing laboratory testing.

A summary of the statistical data is presented in the Multi-Laboratory Precision Tables found in Appendix C. Besides the comparison made to ASTM, AASHTO or MTO precision statements, comparison of the variation between previous test periods is made for each of the tests. Because the materials usually differ from year to year, it is emphasized that the comparison between years should be used only as a guide. It is important to note that the yearly use of different materials will have some effect on the variation exhibited in some tests, while it will have relatively little effect on others. For example, the magnesium sulphate soundness test normally exhibits increased variation as higher mean loss is reported. A coarse aggregate sample having an average mean loss of twenty percent would likely show more variation than a coarse aggregate sample having an average mean loss of ten percent. On the other hand, a sieve analysis could be performed on those same two aggregates, with the percent passing each sieve and the variation being remarkably similar for the two samples.

3.4 PROFICIENCY SAMPLE TESTS

3.4.1 LS-601 - Wash Pass 75 µm (Coarse Aggregate) – Test No. 1

Two hundred and twenty-six laboratories reported results for this test in 2014. Twenty-one outliers were identified and rejected using the iterative technique. The standard deviations of 0.16 and 0.18 obtained in 2014 are significantly lower than the values that were reported in the past three years. The standard deviations obtained in 2014 are also significantly lower than the multi-laboratory variation of 0.20 published in the MTO Test Method LS-601 for aggregates with less than 2.5% material passing the 75 µm sieve and that of the value of 0.22 published by ASTM C 117 for aggregates with 1.5% of material finer than the 75 µm sieve. The mean value of the aggregate used in 2014 consisted of approximately 1.1% material finer than 75 µm, which is within the range of values for which the ASTM and MTO precision statements were established. Further, the coefficient of variation of 15.8% obtained in 2014 is significantly lower than the values of 21.7% reported in 2013 and comparable to the value of 13.5% reported in 2012. The scatter diagram provided in the Appendix D1 shows a combination of random variation and laboratory bias for some laboratories. The laboratories that are identified as outliers should examine their test procedure more closely, especially the achievement of constant dry mass at the beginning and end of the test.

3.4.2 LS-602 - Sieve Analysis (Coarse Aggregate) – Test Nos. 2 to 6

These tests represent the coarse aggregate portion of the Granular A sample gradation. Tests 20-25 carried out on the material passing 4.75 mm sieve as prepared by the participants (samples 3.14 and 4.14) represent the remainder of the gradation. The data is presented in percent passing format and is compared to precision statements developed in the same format by Vogler and Spellenberg[7].

The Granular A samples 1.14A and 2.14A supplied for the sieve analysis test consisted of approximately 54.0% of the material retained on 4.75 mm sieve, and conform to the grading of Granular A materials used in the past MTO Aggregate and Soil Proficiency Sample Testing Programs. The gradings reported for Test Nos. 2-6 represent the combined gradings of coarse and fine aggregates. The proficiency test samples were prepared with the large spinning riffler described in Section 3.2.

The standard deviations obtained in 2014 for all of the sieves, with the exception of 19.0 mm sieve, are found to be significantly lower than the expected variations given in the ASTM C 136 precision statements. In the case of 19.0 mm sieve, the standard deviations of 0.6 and 0.7 obtained are almost twice that of the precision estimate of 0.35 published by ASTM.

Two hundred and twenty-six laboratories reported results for the sieve analysis test in 2014. Outliers were eliminated using the iterative technique. Successive scatter diagrams show a fairly uniform distribution of points about the mean (i.e. a random variation with little

7 Vogler, R.H., Department of Transportation, Michigan, AASHTO Technical Section 1c; T27 and Spellenberg, P.A., AASHTO Materials Reference Laboratory; Unpublished Paper.

laboratory bias). The number of outliers identified varies from sieve to sieve, and ranges from five for the 16.0 mm sieve to a maximum of twelve for 9.5 mm and 4.75 mm sieves.

Possible reasons for outlying observations include factors that impact the measurement process such as sieve condition (state of repair and cleanliness), efficiency of the sieving process and apparatus, initial sample mass, and mass on a given sieve. If your laboratory has performed poorly in this test period, you should inspect your sieves (use CAN/CGSB-8.1-88 or ASTM E11 as guides) and your sieve shaker(s) thoroughly, and, once satisfied that they are in order, perform a sieving efficiency test as described in LS-602 to pinpoint any problems.

3.4.3 LS-603 - Los Angeles Abrasion Loss (Coarse Aggregate) – Test No. 8

Only eleven laboratories reported results for this test in 2014. No outlier was detected by the use of critical value method or iterative technique. Considering the number of observations (11) used, the analysis may not yield any meaningful or representative statistical data. The lower left and upper right quadrants together account for nine of the eleven points, which is evidence of significant laboratory biases. This test shows systematic variation, as was found in previous years. However, the standard deviations obtained in 2014 are comparable to that of the values reported in the past three years.

ASTM precision statements for 19.0 mm maximum size coarse aggregate, with percent loss in the range of 10% to 45%, give a multi-laboratory coefficient of variation of 4.5%. Therefore, the results from two different laboratories should not differ by more than 12.7%. The mean loss of 26.4% in this test is within the range of values for which ASTM C 131 data was established. This year's coefficient of variation (average 4.5%) is consistent with that of the value, 4.5%, given in the ASTM precision statements.

3.4.4 LS-604 - Relative Density of Coarse Aggregate – Test No. 9 and Absorption of Coarse Aggregate – Test No. 10

MTO Test Method LS-604 follows the procedures described in ASTM C 127-12 for the determination of relative density (Test No. 9) and absorption property (Test No. 10) of coarse aggregates. ASTM C 127 provides precision statements only for relative density. It does not provide precision estimates for the absorption property. In the case of LS-604, it provides precision estimates for both relative density and absorption of coarse aggregates with absorption properties less than 2.0%. The precision statements published in LS-604 were established using the data collected for a period of fourteen years, through the MTO Proficiency Sample Testing Program.

Ninety-nine laboratories reported results for these tests in 2014. Six laboratories for relative density and five laboratories for absorption were identified as outliers using the iterative technique. The standard deviations of 0.006 and 0.007obtained for bulk relative density in 2014 are similar to the values reported in 2013 and are consistent with the precision estimate of 0.006 published in the LS-604. Further, the standard deviations obtained in 2014 are one-half of the value of 0.013 published in ASTM C 127. In the case of absorption test, the

standard deviations of 0.078 and 0.079 obtained this year are slightly lower than the precision estimate of 0.09 provided in the LS-604. In addition, the coefficient of variation of 10.6% obtained in 2014 is consistent with the values 6.1% to 12.3% reported in the past three years. The scatter diagrams for both Test Nos. 9 and 10 show a combination of random variation and laboratory bias for some laboratories.

3.4.5 LS-606 - Magnesium Sulphate Soundness (CA) – Test No. 11

Forty-three laboratories reported results for this test in 2014. Four outliers were identified by the use of iterative technique. The scatter diagram shows a pronounced between laboratory bias. Majority of the points, (81%), are accounted in the lower left and upper right quadrants. This test has historically shown high coefficients of variation due to the difficulty of maintaining solution of the correct density and insufficient drying by some laboratories. The average mean loss of 4.8% in this test is significantly lower than the range of values (9% to 20%) for which the ASTM C 88 precision estimate was established. The coefficient of variation of 25% obtained in 2014 is significantly lower than the value of 51.4% reported in 2013 and consistent with that of the value published in the ASTM precision statements. ASTM reports a multi-laboratory coefficient of variation of 25% for coarse aggregate with percent loss in the range of 9% to 20%.

3.4.6 LS-607 - Percent Crushed Particles – Test No. 12 and Percent Cemented Particles – Test No. 7

The coarse aggregate samples supplied did not contain adequate amount of material retained on the 19.0 mm sieve. For this reason, participants were advised to perform the test only on coarse aggregate passing the 19.0 mm sieve and to calculate the weighted average by assigning the same percent crushed particles value as the next smaller fraction (i.e., 19.0 mm - 13.2 mm) for 26.5 mm to 19.0 mm that need not be tested.

This year, two hundred and twenty-six laboratories submitted results for this test. Participants in this test were asked to calculate the weighted average of percent crushed particles using the results of all five fractions specified in the instructions. Two of the participants did not follow the instructions and reported weighted average based on the results of only three fractions. These laboratories were removed from the analyses manually and were identified as outliers. In addition, sixteen laboratories were selected as outliers by employing the iterative technique. The standard deviations of 3.2 and 3.3 obtained in 2014 are significantly lower than the precision estimate of 4.7 published in the MTO LS-607 and the values ranging from 3.7 to 5.9 reported in the past three years. The standard deviations obtained in 2014 are also significantly lower than the value of 6.0 obtained during the 1989 MTO workshop. The average mean value of 76.4% in this test is within the range of values (55% to 85%) for which the MTO precision statements were established. The scatter diagram shows a combination of random variation and operator bias for some laboratories. ASTM has a very similar test method (D 5821) but has not conducted inter-laboratory studies to determine precision and currently publishes precision data (standard deviation of 5.2 for a mean percent crushed particles value of 76.0%) obtained from MTO study. The marked improvement in the multi-laboratory variations obtained in 2013 and 2014 may have resulted

from the clarity that was provided in the latest revision of MTO LS-607 (Revision No. 27), for the calculation of weighted average of percent crushed particles.

3.4.7 LS-608 - Percent Flat and Elongated Particles – Test No. 13

The determination of a flat and/or elongated particle is dependent on operator skill and judgement in using the measurement tool. The ASTM and CSA procedures use a proportional calliper device to measure the *greatest* length or width to thickness ratio. The MTO procedure previously measured the ratio of *mean* length or width to the *mean* thickness (MTO Laboratory Manual Revision 15 and earlier). The MTO procedure (Revision 16 and up) has been modified to agree with the ASTM definition. All participants should be using the latest MTO version of the test method. Flat and elongated particles are defined in the MTO Test Method LS-608 as those pieces whose greatest dimension in the longitudinal axis, compared to the least dimension in a plane perpendicular to the longitudinal axis, exceeds a ratio of 4:1. This test method is similar to that of ASTM D 4791 and uses the same definition, with the exception of ratio, for the flat and elongated particles. In ASTM, the flat and elongated particles are defined as the pieces that exceed a ratio of 3:1 or 5:1. In LS-608, the test sample is separated into number of fractions and the weighted average of percent flat and elongated particles is calculated using the result of every fraction tested.

The coarse aggregate samples supplied did not contain adequate amount of material retained on the 19.0 mm sieve. For this reason, participants were advised to perform the test only on coarse aggregate passing the 19.0 mm sieve and to calculate the weighted average by assigning the same percent flat and elongated particles value as the next smaller fraction (i.e., 19.0 mm - 13.2 mm) for 26.5 mm to 19.0 mm that need not be tested.

This year, two hundred and twenty-six laboratories submitted results for this test. Participants in this test were asked to calculate the weighted average of percent flat and elongated particles using the results of all five fractions specified in the instructions. Two of the participants did not follow the instructions and reported weighted average based on the results of only three fractions. These laboratories were removed from the analyses manually and were identified as outliers. In addition, eight laboratories were selected as outliers by employing the iterative technique. LS-608 provides precision estimate for coarse aggregate passing 19.0 mm and retained on 4.75 mm with percent flat and elongated particles ranging from 2.0% to 9.5%. The standard deviations of 1.7 and 1.8 obtained in 2014 are slightly lower than that of the values (1.8 to 2.5) reported in 2012 and 2013. The multi-laboratory variations obtained in 2014 are also significantly lower than the precision estimate of 2.3 published in LS-608. The average mean value of 4.7% in this test is within the range of values (2% to 9.5%) for which the MTO precision statements were established.

ASTM D 4791 is similar to LS-608 for comparison of multi-laboratory precisions obtained. In ASTM, the precision estimates are provided for individual fractions ranging from 19.0 mm to 4.75 mm (19 mm to 12.5 mm, 12.5 mm to 9.5 mm, and 9.5 mm to 4.75 mm), and the estimates are based on the coefficient of variation. A direct comparison of the precision estimates from ASTM is not appropriate with that of the estimates provided in LS-608. The precision estimates published in LS-608 are on the basis of standard deviation, and was

estimated from the weighted averages calculated using the results of four fractions ranging from 19.0 mm to 4.75.mm.

The scatter diagram provided in the Appendix D1 shows a combination of random variation and laboratory operator bias for some laboratories. In general, laboratories that reported values in excess of 8% or less than 1.5% should critically examine their equipment and procedure.

3.4.8 LS-609 - Petrographic Analysis (Coarse Aggregate) – Test No. 14

The coarse aggregate examined in 2014 was clear stone from the Stewart Pit, located 5 km south west of Orillia, Ontario (MAIDB Number O11-144). This source is situated within the north-northeast portion of the Oro Moraine and has been listed on MTO's aggregate source lists for structural concrete coarse aggregate for many years.

Worksheets were submitted from thirty three analysts representing twenty five laboratories. As some laboratories had multiple analysts, for the purpose of this report, each analyst is assigned an individual laboratory number. Each analyst is referred to by their laboratory number. Test results are summarized in Table 5. Graphical representations of significant rock type(s) categories are included in Figures 2-10.

Calculation and typographical errors were noted on submissions from 10 laboratories. In several instances PN worksheets were not completed in full and in a few cases, the results were illegible and difficult to discern. Participants are reminded that it is required to complete the worksheets in full, to report the PN as a whole number, and to ensure that the data entered on the worksheets are legible. Please see Appendix E1 for a summary of the Petrographic Number Test submissions received for 2014.

Based on the submitted worksheets, the sample contained approximately 78 % carbonate aggregate and 22 % siliceous aggregate. The range of reported siliceous aggregates was 15.7 % to 33.7 %. The range of reported carbonate aggregates was 65.3 % to 84.3 %. Also based on the worksheets, the sample contained an average of 93.4 % Good category aggregate, 5.4 % Fair category aggregate, and 1.3 % Poor category aggregate, which translates into an average PN value of 117. The aggregate quality indicated by this PN is also denoted by average values obtained in other testing of this material, i.e., Micro-deval abrasion loss (~11.9 %), unconfined freeze-thaw loss (~8.7 %) and magnesium sulphate soundness loss (~4.7 %). Four laboratories reported very small amounts of Deleterious category aggregate that consisted of decomposed volcanic-gneiss-schist, friable carbonate, and clay.

In general, aggregates classified within the Good category consisted mainly of hard to medium hard carbonate (Rock Types 01 and 20), and hard granite, granite gneiss, gabbro, and amphibolite gneiss to schist (Rock Types 04 and 08). The total reported carbonate aggregate content within the Good category ranged from 49.1 % to 81.8 %, with an average of 72.7 %. The total reported siliceous aggregate content within the Good category ranged from 14.8 % to 31.3 %, with an average of 20.8 %. The proportion of hard versus medium-hard carbonate varied widely among analysts. The classification of the particle into Rock

Type 01 or 20 depends mainly on the analysts' judgement as to the scratch hardness of the particles. However, both types are in the Good category.

Labs 96 and 188 reported 0.1 % each of friable carbonate and decomposed volcanic-gneiss-schist in one of the two samples examined. Labs 40 and 96 both reported small amounts of clay in both samples.

The reported range in PN values for the 2014 material was 102 to 179. Labs 30, 38, 79, 86 and 114, were identified as statistical outliers by iterative technique, based strictly on reported PN values (see Test 14 scatterplot, p.77). However, a statistical analysis of the reported PNs does not fully capture the performance of analysts using subjective evaluation, it is also necessary to examine the results in greater detail to ensure analysts are identifying rock types correctly with respect to both geological classification and quality classification. To this end the results were examined in more detail to identify laboratories that either failed to report the main rock types in reasonable quantities, or that reported excessive amounts of particular materials that cannot be reasonably explained by material source variability or sample preparation. Additionally some analysts reported the presence of rock types that are not native to the source location.

Test results from Labs 30, 38, 79, 86 and 114 (identified as outliers) as well as Labs 61 and 206 are deemed unacceptable for the following reasons:

Lab 30 reported large amounts of hard or medium hard sandy carbonate Rock Type 2 – amounts of 27.6 % and 19.4 % respectively. Lab 30 also reported 6.1 % sandy, soft carbonate Rock Type 40 in sample 1.14. Analysts are reminded that to classify a rock as "sandy" it must contain between 5 and 49% sand-sized quartz grains, i.e., those ranging in size between 63 μm and 2 mm (Tucker 1996, Wentworth 1922, and Lane et al. 1947; see Table 2 in LS-609 R29).

Lab 38 did not report any hard or medium hard carbonate in their samples (Figure 10). Only chert-bearing carbonate rock types were reported: slightly cherty carbonate (49.1 %, 55.7 %), chert-cherty carbonate with less than 20 % leached chert (28.7 %, 21.3 %), and chert-cherty carbonate with greater than 20 % leached chert (2.7 %, 4.0 %) – Rock Types 21, 26 and 45 respectively (Appendix E1). This suggests difficulties in the geological identification of chert versus carbonate. Analysts are reminded that the Moh's hardness of chert is seven, equivalent to that of crystalline quartz, therefore it should not scratch easily with a knife and will typically leave a grey streak of metal transferred from the blade to the particle.

Lab 38 also reported significantly less Good category carbonate aggregate (49.1 %, 55.7 %) compared with the other labs (Figure 7). The range of good carbonate values reported by all labs was 49.1 % to 81.8 % with, an average of 72.7 %. Removing Lab 38 narrows the range from 61.1% to 81.8 %, with an average of 73.3 %. Lab 38 also reported the highest amounts of Fair category aggregate (32.8 %, 25.5 %) and Fair category carbonate aggregate (28.7 %, 21.3 %) (Figures 4 and 8). This indicates difficulties in properly assessing the correct quality category into which materials should be placed.

Lab 61 reported Marble Rock Type 23, and in amounts of 5.4 % and 7.3 % respectively (Appendix E1). Although not impossible, it is extremely unlikely that this rock type was present in the source tested this year.

Lab 86 reported Sibley Group Rock Type 80 in amounts of 5.4 % and 7.3 % respectively (Appendix E1). The Sibley Group is a group of three Proterozoic sedimentary rock formations: Rossport Formation, Kama Hill Formation and Pass Lake Formation that occur in the Thunder Bay – South Lake Nipigon - Nipigon area. The distribution of the Sibley Group is limited to bedrock outcrops in these geographic areas and in the surficial deposits that overlie, and are proximal to these areas. It is extremely unlikely that this rock type would be found within the source tested. Sibley Group terminology should only apply where the user is aware of the location and geology of the source and is familiar with utilization of the terminology. Lab 86 also reported large amounts of chert-cherty carbonate with greater than 20 % leached chert Rock Type 45 in amounts of 8.4 % and 9.3 % (Appendix E1). Lab 86 also had the highest reported values of poor aggregate at 8.4 % and 11.2 % (Figure 5, Appendix E1). The range of poor aggregate reported by all labs was 0 to 11.2 % with an average of 1.3 %. Removing Lab 86 narrows the range to 0 to 4.2 % with an average of 1.0 %. All of this suggests difficulties in both the geological classification and in properly assessing the correct quality category into which materials should be placed.

Lab 206 reported total amounts of siliceous and carbonate aggregates that diverged significantly from the average reported values (Figures 6 and 7). Total siliceous aggregate content reported by Lab 206 was 31.9 % and 33.7 %. The range in reported siliceous aggregate values for all labs was 15.7 % to 33.7 % with an overall average of 22.1 %. Removing Lab 206 narrows the range from 15.7 % to 26.8 % with an average of 21.8 %. Total carbonate aggregate content reported by Lab 206 for samples 1.14 and 2.14 was 67.4 % and 65.3 % respectively. The range in total carbonate aggregate content reported by all labs was 65.3 % to 84.3 % with an overall average of 77.7 % (Table 5). Removing Lab 206 narrows the range from 73.3 % to 84.3 %, with an average of 78 %.

The divergence of reported values from the general groupings suggests difficulty in the correct geological identification of basic rock types. Distinguishing between carbonate versus siliceous aggregates is one of the most basic distinctions to be made when employing this test method.

Analysts are also reminded that most carbonate aggregates, in particular limestone, $Ca(CO_3)_2$ will effervesce vigorously when dilute hydrochloric acid is applied. Dolostones will generally not show much visible reaction when acid is applied directly to the rock. However, when acid is applied to the powder produced from scratching dolomite $(Ca, Mg)(CO_3)_2$, it will effervesce (although somewhat less vigorously compared with limestone). Almost all of the carbonate present in this sample consisted of limestone to dolomitic limestone (strong effervescence).

The similar ASTM standard for this test, C-295, does not report a petrographic number and has no precision statement.

Table 5. Summary of Petrographic Results, LS-609.

	Range %	Median %	Average %	*MTO Petrographer*
Petrographic Number	102 - 179	113	117	*124*
% Good Aggregate	64.5 – 98.8	94.5	93.4	*91.4*
% Fair Aggregate	1.1 – 32.8	4.0	5.4	*6.3*
% Poor Aggregate	0 – 11.2	0.7	1.3	*2.4*
% Deleterious Aggregate	0 – 0.4	0	0	*0*
% Total Siliceous Aggregate	15.7 – 33.7	21.9	22.1	*23.6*
% Total Carbonate Aggregate	65.3 – 84.3	77.9	77.7	*75.6*
% Good Siliceous Aggregate	14.8 – 31.3	20.6	20.8	*20.8*
% Good Carbonate Aggregate	49.1 – 81.8	73.5	72.7	*70.6*
% Fair Siliceous Aggregate	0 - 6	0.8	1.2	*1.8*
% Fair Carbonate Aggregate	0.1 – 28.7	2.7	4.0	*4.2*

N = 33 analysts from 25 laboratories, 66 analyses total.
Results for the average of two samples analysed by the MTO Petrographer are provided for reference.

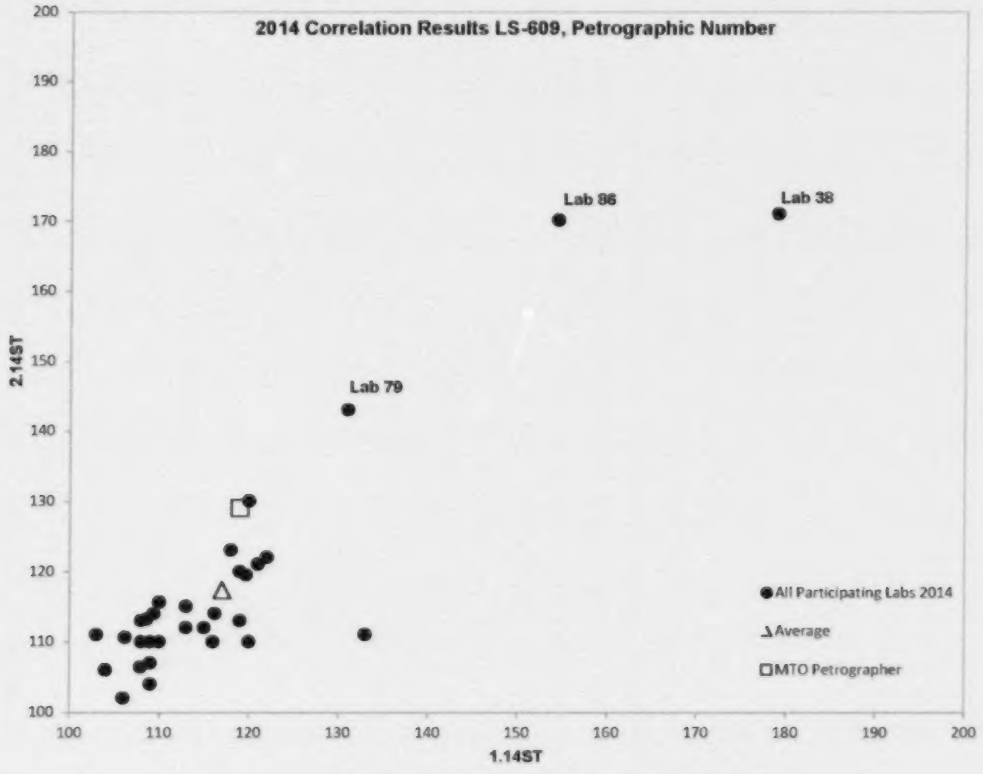


Figure 2. Petrographic Number Test Results.
N=33 Labs

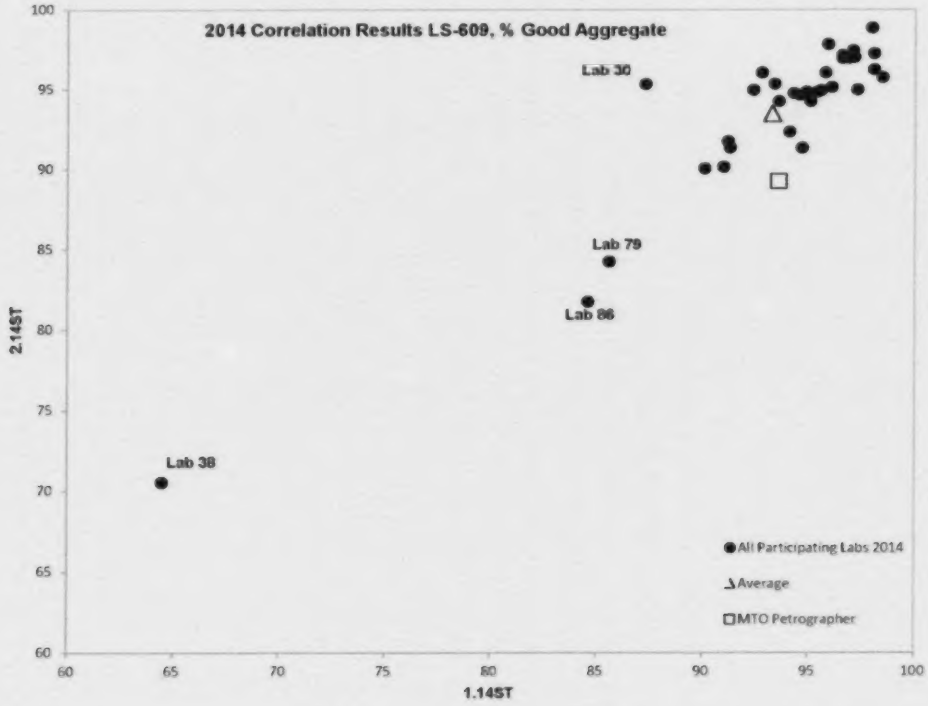


Figure 3. Percent of Good Category Aggregate Reported.
N=33 Labs

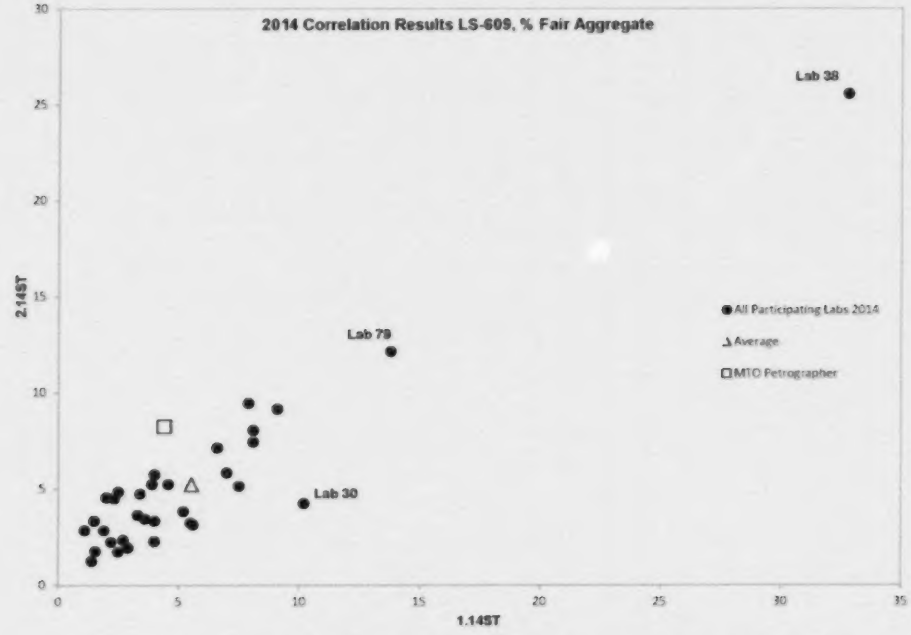


Figure 4. Percent of Fair Category Aggregate Reported.
N=33 Labs

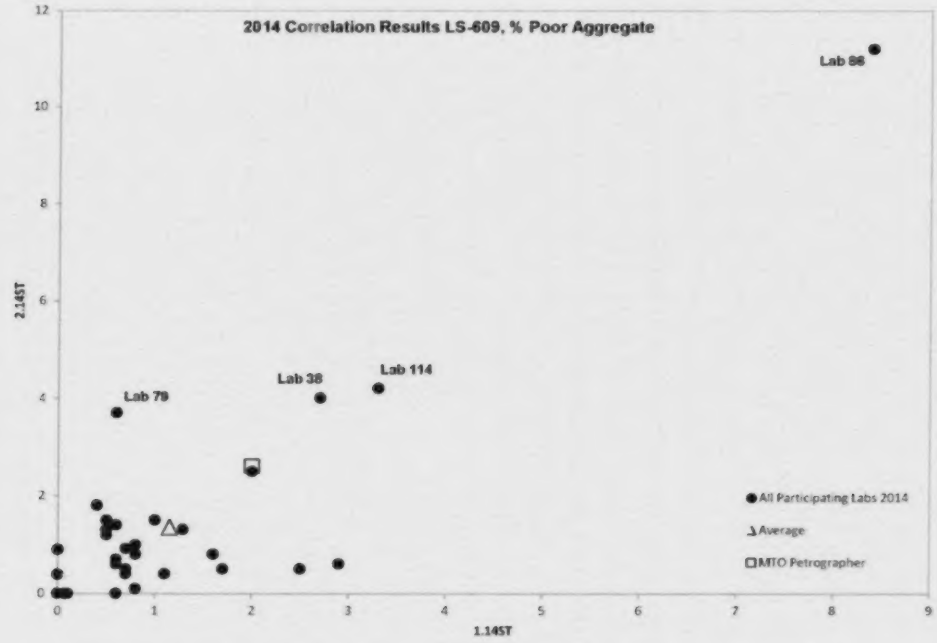


Figure 5. Percent of Poor Category Aggregate Reported.
N=30, Labs 61, 77 and 260 did not report any quantity in either sample.

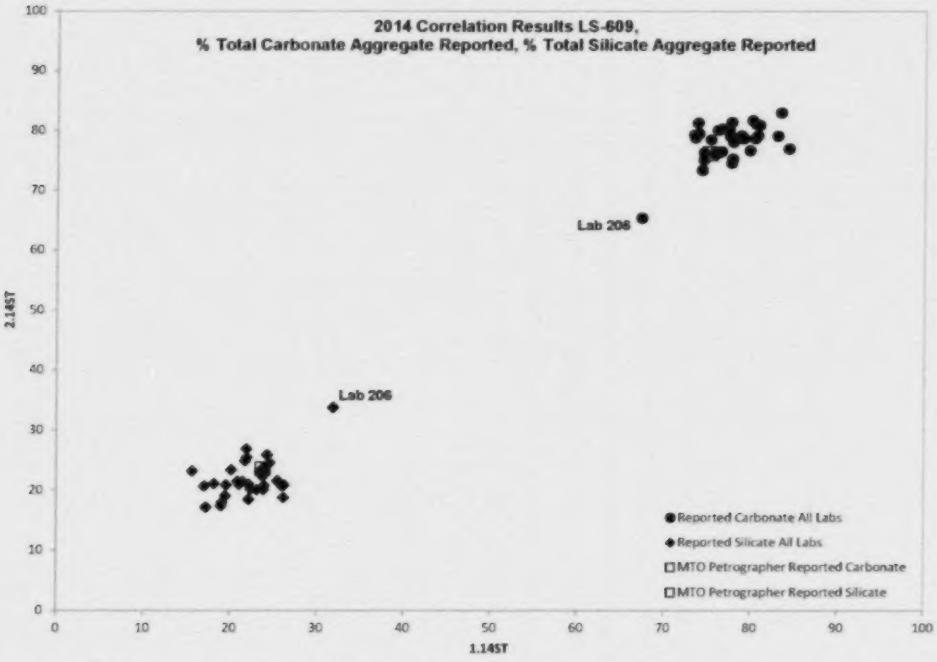


Figure 6. Percent of Total Carbonate Aggregate Reported, and Percent of Total Siliceous Aggregate Reported.
N=33

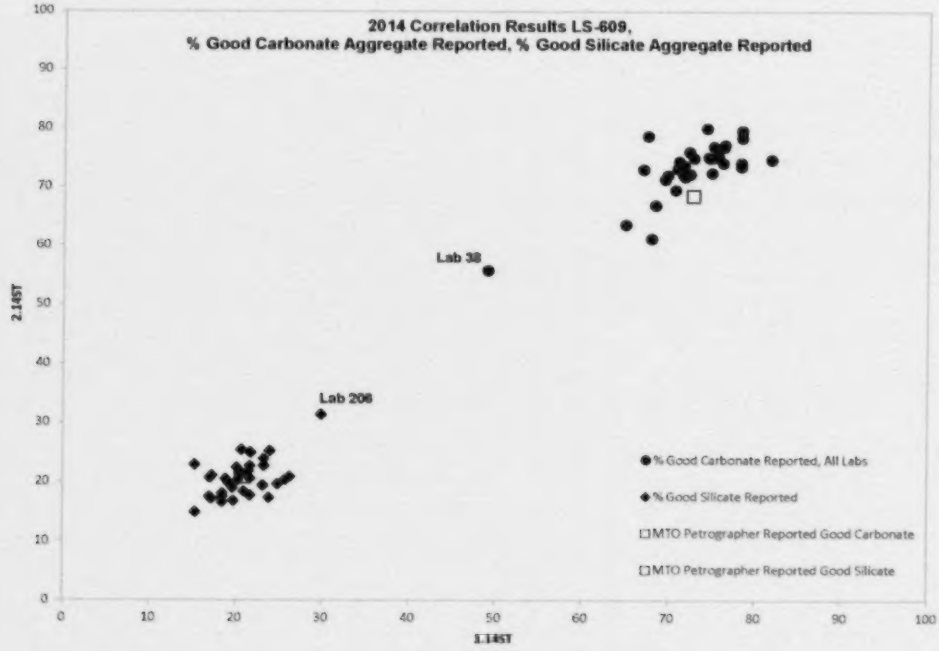

2014 Correlation Results LS-609,
% Good Carbonate Aggregate Reported, % Good Silicate Aggregate Reported
Lab 38
Lab 206
% Good Carbonate Reported, All Labs
% Good Silicate Reported
MTO Petrographer Reported Good Carbonate
MTO Petrographer Reported Good Silicate
2.14ST
1.14ST

Figure 7. Percent of Good Category Carbonate Aggregate Reported and Percent of Good Category Siliceous Aggregate Reported.
N=33

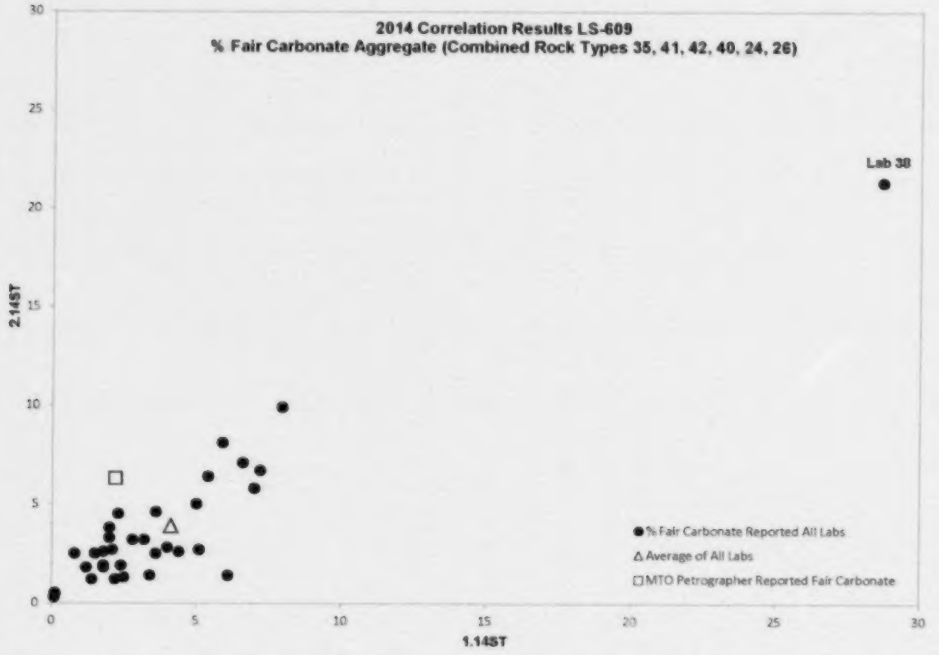

2014 Correlation Results LS-609
% Fair Carbonate Aggregate (Combined Rock Types 35, 41, 42, 40, 24, 26)
Lab 38
% Fair Carbonate Reported All Labs
Average of All Labs
MTO Petrographer Reported Fair Carbonate
2.14ST
1.14ST

Figure 8. Percent of Fair Category Carbonate Aggregate Reported.
N=33

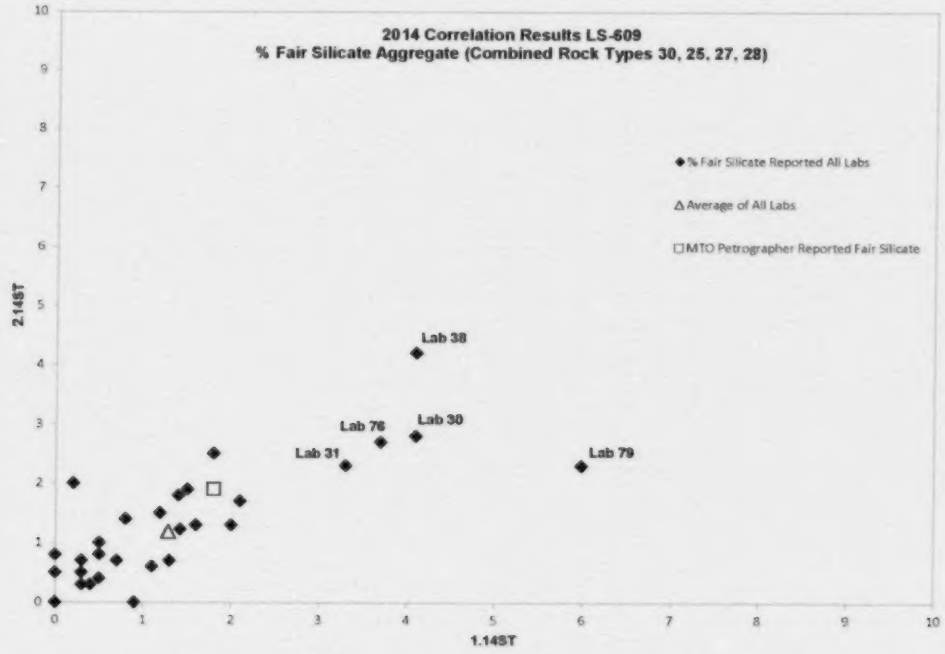


Figure 9. Percent of Fair Category Siliceous Aggregate Reported.
N=33

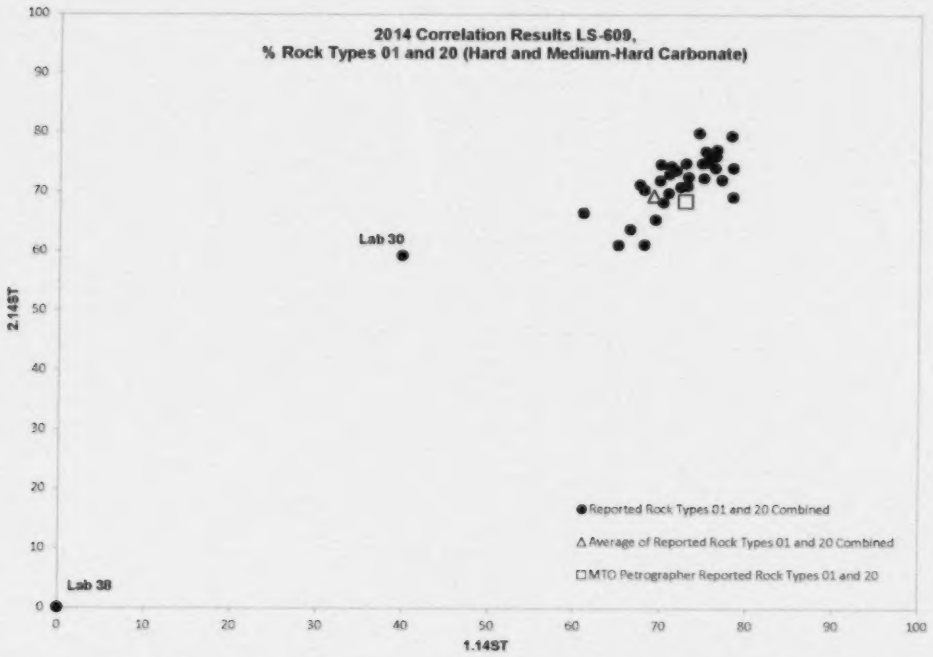

2014 Correlation Results LS-609,
% Rock Types 01 and 20 (Hard and Medium-Hard Carbonate)
Lab 30
Lab 38
●Reported Rock Types 01 and 20 Combined
△Average of Reported Rock Types 01 and 20 Combined
□MTO Petrographer Reported Rock Types 01 and 20
2.14ST
1.14ST

Figure 10. Percent of Hard and Medium Hard Carbonate Aggregate Reported.
N=32

3.4.9 LS-616 - Petrographic Examination (Fine Aggregate)

The fine aggregate examined in 2014 was concrete sand from the Stewart Pit, located 5 km south west of Orillia, Ontario (MAIDB Number O11-144). Twelve analysts submitted worksheets showing subdivision according to rock/mineral type for samples 1.14 and 2.14. As some laboratories had multiple analysts, for the purpose of this report, each analyst is assigned an individual laboratory number. The results were evaluated by C.A. MacDonald, MTO Petrographer and are shown in Appendix E2.

The results indicate an average composition of approximately 52% silicate and 46% carbonate minerals and lithologies. The silicate portion consisted mostly of Precambrian Shield granite, granitic gneiss, quartz, feldspar, gabbro and metabasalt. Sandstone was also reported in minor quantities by several analysts. The carbonate portion of the sample included mostly light grey, very fine-grained micritic and locally stylolitic limestone (on coarser sieve fractions) derived mainly from the Gull River and Bobcaygeon Formations that dominate the bedrock in the vicinity of the source area. The remaining 2% of the sample consisted mainly of mica that was concentrated predominantly on the finest three sieve fractions (300 µm, 150 µm and 75 µm). Eight labs reported minor amounts of chert, mainly on the coarsest three sieves. Minor amounts of cemented particles were noted by all analysts, concentrated on the coarsest three sieves. Cemented particles typically consisted of one dominant host particle with one or more smaller particles adhering to it. Lab 183 was the only lab to report significant shale content on four of the fractions tested. Lab 183 completed more than the minimum 200 particles for each fraction and reported results to the second decimal place.

Individual carbonate content for each sieve fraction is summarized in Table 6. As a cross-check, MTO also completed LS-613, insoluble residue testing (IR) on individual fractions and on an overall representative sample. (The IR test indirectly determines the amount of carbonate minerals, which are dissolved when exposed to a hydrochloric acid solution. After complete digestion, the remaining residue consists of the non-carbonate components of the sample.) Results of the IR testing are summarized in Table 7. A comparison of reported petrographic identification and insoluble residue determination of carbonate content is given below:

- Average petrographic carbonate content of the total sample was 45.8 %, ranging from 37.2 % to 54.0 %. IR data indicates a total carbonate content of 48.5 %.
- Average petrographic carbonate content of the P4.75/R2.36 fraction was 72.1 %, ranging from 59.5 % to 79.0 %. IR data for this fraction was 72.0 %.
- Average petrographic carbonate content of the P2.36/R1.18 fraction was 63.7 %, ranging from 51.0 % to 74.5 %. IR data for this fraction was 70.3 %.
- Average petrographic carbonate content of the P1.18/R600 fraction was 48.8 %, ranging from 41.0 % to 56.5 %. IR data for this fraction was 52.7 %.

- Average petrographic carbonate content of the P600/R300 fraction was 32.0 %, ranging from 20.5 % to 50.8 %. IR data for this fraction was 32.1 %.

- Average petrographic carbonate content of the P300/R150 fraction was 18.5 %, ranging from 6.5 % to 35.5 %. IR data for this fraction was 20.4 %.

- Average petrographic carbonate content of the P150/R75 fraction was 13.2 %, ranging from 5.0 % to 22.8 %. IR data for this fraction was 20.8 %.

In general, the IR data correlates well with the reported petrographic carbonate contents for individual fractions. Analysts that reported low amounts of carbonate or values that deviated significantly on either side of the averages and/or the amounts indicated by the insoluble residue testing should re-examine their samples, in particular on coarser sieve fractions as the carbonate rock types present should have been readily identified. In general, results from Labs 183, 152 and 88 tended to deviate from the averages more than other labs.

Possible reasons for the wide range in reported carbonate for the finer fractions may partly lie in the difficulty of correctly identifying the minerals at such a small particle size. Some tips to aid the analyst include a weak acid etch of the slide as indicated in MTO test method LS-616 prior to examination. The acid will generally remove any dusty coatings on the aggregate particles and also may make carbonates more readily identifiable at small sizes. Practitioners are cautioned that there is a danger of dissolving too much carbonate material if too strong an acid is used or if the material is left in contact with the acid for too long a time period. Generally 1 to 3 seconds is sufficient contact time.

Carbonate present in this sample generally appeared white to light grey and greyish beige with yellowish to peach colours less common, opaque to translucent, and also may have had a "frosted" appearance. Another tip to aid in identification is to change the background colour under the glass slide. The background under many stereomicroscopes often tends to be white, which does not provide good contrast when trying to distinguish minerals such as transparent, colourless quartz from generally white carbonates.

Rare partial rhombohedral crystal shapes and cleavage as well as calcite twinning was also observed by the author in the P150/R75 fraction. Other phases present in this fraction may have included, but are not limited to mainly colourless, transparent, glassy lustre quartz (~60%); feldspar (K-feldspar and plagioclase, 5-10%), amphibole (~5%), biotite mica (~10%) and almandine garnet. Use of fine needles as tools for probing and/or scratching the particles is recommended. A fine needle syringe filled with hydrochloric acid is also a useful tool for applying small droplets of acid to test for reaction of carbonates, particularly in the finer size fractions.

Another tip to aid in identification of some carbonates is through the use of various staining techniques that are well published in the older petrographic literature, e.g., Lemburg (1887) and Dickson (1965). Most of these techniques are fast, quite practical and may be an economical way of increasing the accuracy of analyses particularly on the finer sized fractions. One of these techniques for identification of calcite is through the use of Alizarin

red S staining. To perform: begin by etching the slides in a dilute solution of HCL (0.5% to 1.5 % concentration). Mix 0.2 g of Alizarin red S in 100 ml of 1.5 % HCl solution until it dissolves completely. Submerge the etched slide in the stain solution for between 10 seconds and 2 minutes (amount of time will depend on particle size being examined and mineralogy and/or rock types present). Rinse the slide carefully with water being careful not to completely rinse away the stain (it is water soluble), or to dislodge the particles from the slide. Allow the slide to dry by standing it vertically against a wall or other surface so that the water runs off. Limestone present in the sample should stain red to pale pink. Dolomite, if present will not take the stain.

Mica contents on the finest three sieve fractions were also examined in detail (Table 8). Average mica content reported on the P600/R300 fraction was 1.5 %, with a range of 0 % to 3.5 %. Average mica content reported on the P300/R150 fraction was 4.4 %, with a range of 1.0 % to 9.0 %. Average mica content reported on the P150/R75 fraction was 6.9 %, with a range of 2.0 % to 17.4 %. Possible reasons for the wide range, particularly on the P150/R75 fraction, could be due to differences in sample preparation. Care must be taken during slide preparation to avoid excessive preferred orientation of the flat, platey mica particles. If the slide is prepared in such a manner that allows for a preferred orientation of the mica particles to develop in a direction either parallel or perpendicular to the glass slide on which they are mounted, then it can result in higher or lower values obtained from a point count, respectively.

Tips for sample preparation to avoid preferred orientation of mica particles include mixing the sample well prior to application to avoid segregation. "Sprinkling" of a fairly full tablespoon of the particles onto a slide held at a slight angle to the fall direction also helps with achieving random orientations. Colourless epoxy should be applied sparingly in the preparation of the finer particle sizes as excessive amounts of epoxy will tend to coat or envelop the particles. This can be particularly troublesome where the epoxy used is of a similar refractive index to the minerals intended to be examined.

Several laboratories did not report the minus 75 µm fraction of the gradation. Participants are reminded that for the purpose of calculating the weighted percent of components, the minus 75 µm fraction needs to be included, (assumed to have the same composition as the retained 75 µm sieve fraction).

The similar ASTM standard for this test, C-295, has no precision statement.

Table 6. Petrographic Results for Carbonate Content, LS-616.

Carbonate Content – Weighted Average Total Sample				
Fraction	**Range %**	**Median %**	**Average %**	***MTO Petrographer***
P4.75	37.2 to 54.0	46.0	45.8	*47.3*
Carbonate Content – Individual Sieve Fractions				
Fraction	**Range %**	**Median %**	**Average %**	
P4.75/R2.36	59.5 – 79.0	73.4	72.1	*69.0*
P2.36/R1.18	51.0 – 74.5	65.0	63.7	*70.5*
P1.18/R600	41.0 – 56.5	49.8	48.8	*50.0*
P600/R300	20.5 – 50.8	31.3	32.0	*31.5*
P300/R150	6.5 – 35.5	17.8	18.5	*23.0*
P150/R75	5.0 – 22.8	13.0	13.2	*15.0*

N = 24
MTO Petrographer results (one sample) provided for reference.

Table 7. Results of Insoluble Residue Testing on (Petrographic) Fine Aggregate Sample, LS-613

Insoluble Residue Results – Representative Sample				
Fraction	**Mass Tested (g)**	**R75µm IR %**	**Total IR %**	**Carbonate %**
P4.75	154.8	49.7	51.5	48.5
Insoluble Residue Results – Individual Sieve Fractions				
Fraction	**Mass Tested (g)**	**R75µm IR %**	**Total IR %**	**Carbonate %**
P4.75/R2.36	134.8	26.7	28.0	72.0
P2.36/R1.18	126.4	28.2	29.7	70.3
P1.18/R600	124.4	45.9	47.3	52.7
P600/R300	113.8	67.0	67.9	32.1
P300/R150	117.5	78.8	79.6	20.4
P150/R75	95.2	76.3	79.2	20.8

Table 8. Petrographic Results for Mica Content, LS-616.

Mica Content – Weighted Average Total Sample				
Fraction	**Range %**	**Median %**	**Average %**	***MTO Petrographer***
P4.75	0.3 - 2.4	1.0	1.3	*1.7*
Mica Content – Finest Three Sieve Fractions				
Fraction	**Range %**	**Median %**	**Average %**	
P600/R300	0 – 3.5	1.4	1.5	*1.5*
P300/R150	1.0 – 9.0	3.5	4.4	*6.0*
P150/R75	2.0 – 17.4	5.5	6.9	*11.0*

N = 24
MTO Petrographer results (one sample) provided for reference.

3.4.10 LS-613 - Total Percentage of Insoluble Residue – Test No. 15 and Percentage of Insoluble Residue Retained 75 µm – Test No. 98

This is the first time the determination of insoluble residue of carbonate aggregates (MTO LS-613) has been included in the MTO Proficiency Sample Testing Program. MTO LS-613 is similar to ASTM D3042, insoluble residue in carbonate aggregates, but the scope and procedure to determine the total percentage of insoluble residue and percentage of insoluble residue retained 75µm in LS-613 differ from that of ASTM. In addition, mass and the maximum size of the aggregates recommended for the test sample in LS-613 differ from D3042.

Only sixteen laboratories reported results for this test. Considering the number of observations (16), the analysis may not yield any meaningful or representative statistical data to evaluate the performance of the participants. Iterative technique was used to remove outliers from both sets of data, i.e., data for Test Nos. 15 and 98. One outlier from the data for total percentage of insoluble residue and five outliers from the results for percentage of residue retained 75 µm were removed. Majority of the data points on the scatter diagrams are accounted in two quadrants (1 and 2 for Test No. 15 and 1 and 4 for Test No. 98).

The standard deviations of 8.8 and 6.7 obtained for total percentage of insoluble residue are 2.5 to 3 times that of the precision estimate published in ASTM D3042. Based on the findings published in ASTM, the precision or multi-laboratory variation appears to vary with the level of insoluble residue. The intermediate level of insoluble residue was found to have the highest variability. In the case of percentage of insoluble residue retained 75 µm, the standard deviations 2.4 and 4.0 obtained are close to the precision estimate of 3.1 published by ASTM. MTO LS-613 may have to be revised to reduce the multi-laboratory variation and to improve performance. The data from the MTO proficiency sample testing program may be used to evaluate the future performance of this test method.

3.4.11 LS-618 - Micro-Deval Abrasion (Coarse Aggregate) – Test No. 16

Seventy-eight laboratories reported results for this test in 2014. The test method requires reporting of control sample results to demonstrate that the testing process is in control. This year, one laboratory reported control sample results outside the established range and this lab was excluded from the analysis and identified as an outlier. In addition, two outliers were rejected using the iterative technique.

The multi-laboratory coefficient of variation of 5.4% published in the LS-618 is for 19.0 mm maximum size aggregate with abrasion losses in the range from 5% to 23%. The mean loss of 11.8% in this year's program is within the range of values for which the precision estimates were established. The average coefficient of variation of 5.5% obtained in 2014 is consistent with the value of 5.4% published in LS-618. However, it is slightly higher than that of the values reported in the past three years (4.3% to 5.4%). The scatter plot for this test shows random variation with little laboratory bias.

3.4.12 LS-614 - Freeze-Thaw Loss – Test No. 17

The coarse aggregate samples supplied did not contain adequate amount of material retained on the 19.0 mm sieve. For this reason, participants were advised to perform the test only on coarse aggregate passing the 19.0 mm sieve and to calculate the weighted average by assigning the same freeze-thaw loss value as the next smaller fraction (i.e., 19.0 mm - 13.2 mm) for 26.5 mm to 19.0 mm that need not be tested.

Sixty-one laboratories reported results for this test in 2014. The test method requires reporting of laboratory control sample losses to demonstrate that the testing process is in control. This information is used to alert the laboratories to testing deficiencies. Without testing of the reference material, the test is invalid (see LS-614, Section 9.1). This year, one of the laboratories reported control sample result outside the established range for the material. In addition, two outliers were identified using the iterative technique.

The multi-laboratory coefficient of variation of 21.6% published in LS-614 is for coarse aggregate with freeze-thaw losses in the range of 3% to 18%. The coefficient of variation of 22.8% obtained in 2014 is consistent with the value of 21.6% published in the LS-614. This value is also significantly lower than that of the values 29.3% to 34.7% reported in the past two years. The majority of the points on the scatter plot (88.5%) are accounted in the lower left and upper right quadrant, indicating a pronounced laboratory bias.

It is likely that there are two main reasons for the spread of the data for this test: insufficient damage caused by freezing too rapidly or difference in sieving intensity. The laboratories that reported freeze-thaw losses higher than 12.5% should modify their processes to try and achieve losses closer to the mean loss of the control aggregate. Appendix 1 of LS-614 gives a procedure for determining and adjusting sieving time for quantitative analysis. Each laboratory must establish their sieving time, if the mechanical shaker and diameter of sieves are different from that were used to establish the sieving time provided in the Appendix 1 of LS-614.

3.4.13 LS-602 - Sieve Analysis (Fine Aggregate) – Test Nos. 20-25

The test samples for this procedure were prepared by the participants from the material passing the 4.75 mm sieve of the coarse aggregate gradation. This process closely follows the normal testing procedure in which the laboratory prepares its own test samples from the field sample. The scatter diagrams for the fine aggregate sieve analysis show random variation with little laboratory bias. The standard deviations of the fine sieves in 2014 are noticeably lower than that of the values reported in the past three years. The multi-laboratory variations, with the exception of 150 µm and 75 µm sieves, are found to be consistent with the values published in the ASTM C 136 precision statements. In the case of 150 µm and 75 µm sieves, the standard deviations obtained (0.3 to 0.5) are significantly lower than the value of 0.65 published by ASTM.

As in previous inter-laboratory studies, it was found that the precision of the test varies as a function of the amount of material retained on any sieve. The smaller the amount of material

retained, the more efficient the sieving process and the better the precision. When there is a small amount of material retained on a sieve (one layer of particles or less), the particles have a greater chance of falling through the sieve in a given time.

The number of outliers identified varies from sieve to sieve, and ranges from twelve for 1.18 mm, 600 µm, 300 µm and 75 µm sieves to a maximum of twenty for the 150 µm sieves. Outlier laboratories with a very low percent passing the 75 µm sieve should inspect their sieves, as low percent passing may be the result of the sieve being blinded when washing the sample. An ineffective washing process will also result in a low percent passing this sieve.

3.4.14 LS-605 - Relative Density of Fine Aggregate – Test No. 27 and Absorption of Fine Aggregate – Test No. 28

Participants in the program were asked to test the samples according to MTO Test Method LS-605. This test method follows ASTM C 128, except that it requires the removal of materials finer than 75 µm from the test specimen by washing. LS-605 requires the test specimens to be prepared in duplicate and washed on the 75 µm sieve until all of the material finer than 75 µm is removed. The presence of material finer than 75 µm in the test specimens can result in lower relative densities and higher absorption values.

In the past, MTO was using the precision estimates published in the ASTM C 128 for both relative density and absorption to compare and evaluate the multi-laboratory variations obtained from the MTO proficiency sample testing program. Considering the difference in preparation of test specimen between the ASTM C 128 and LS-604, use of the multi-laboratory variations published in the ASTM may not be appropriate to evaluate the performance of the participating laboratories. Since 2012, MTO has been using the precision estimates developed from its proficiency sample test data collected over a period of fourteen years. The latest revision of this test method provides precision estimates for both relative density and absorption of fine aggregates with absorption properties less than 2.0%.

Ninety-eight laboratories reported results for these tests in 2014. Eight outliers for relative density (Test No. 27) and six outliers for absorption (Test No. 28) were selected using the iterative technique. As in previous years, greater variation exists in this test compared to the relative density test on coarse aggregate. It is imperative that differential drying of the various sized particles be avoided by *constant* stirring of the sample under the air current during the drying process. As short as 30-second periods of rest can be detrimental to the outcome of the test results. Differential drying of the particles is known to cause premature collapse in the cone test used to judge the saturated surface dry state. The resulting test observations are lower relative densities and higher absorption values.

The standard deviations obtained in 2014 for both relative density (0.009 and 0.011) and absorption (0.12 and 0.13) are slightly lower than the values published in the LS-605 and that of the values reported in the past three years (refer Appendix C). As in the previous studies, the multi-laboratory variations obtained in 2014 are significantly lower than that of the values published in the ASTM C 128 precision statements. ASTM publishes a multi-laboratory variation of 0.023 and 0.23 for relative density and absorption, respectively for

fine aggregates with absorption properties less than 1.0%. The scatter plots for both tests show a pronounced between laboratory bias.

3.4.15 LS-621 - Amount of Asphalt Coated Particles – Test No. 30

Two hundred and twenty-five laboratories reported results for this test in 2014. Fourteen laboratories were identified as outliers using the iterative technique. Scatter diagram provided in the Appendix D1shows a random variation with little laboratory bias. LS-621 provides precision estimate for 19.0 mm maximum size coarse aggregate mixed with asphalt coated particles in the range of 25% to 55%. The average mean values of 45.7% and 39.4% reported by the laboratories are well within the range of values for which the precision estimate was developed. The standard deviations of 4.9 and 5.0 obtained in 2014 are significantly higher than the precision estimate of 3.9 published in the LS-621 and the values (2.9 and 3.0) reported in 2013. Laboratories that reported values of less than 29% and in excess of 56% should critically evaluate their interpretation of the definition and re-examine their samples. There is no comparable or similar ASTM test procedure.

3.4.16 LS-623 - Moisture-Density Relationship (One-Point) – Test Nos. 31-33

Participants were asked to perform this test on the material passing the 19.0 mm sieve of the Granular A samples 1.14A and 2.14A supplied. One hundred and fifty-six laboratories reported results for this test in 2014. Twelve outliers for the wet density (Test No. 31) and eleven outliers for optimum moisture (Test No. 33) determinations were rejected using the iterative technique. The standard deviations obtained in 2014 for all three tests, i.e. wet density, dry density and optimum moisture content are consistent with that of the values reported in the past three years and are significantly lower than the precision estimates published in LS-623.

The scatter diagrams show a combination of random variation and laboratory bias for some laboratories. Possible causes for the laboratory bias may be operator error and the use of 101.6 mm diameter mould, even though the participants were requested to use only the 152.4 mm diameter mould. This test also requires significant operator skill to obtain the point within the band in the first attempt. Those laboratories with poor ratings should examine their equipment and procedure to discover the causes for this variation. There is no comparable or similar ASTM test procedure. However, ASTM D 698 covers the laboratory compaction characteristics of soils and reports precision estimates from the tests conducted only on clayey soils.

3.4.17 LS-619 - Micro-Deval Abrasion (Fine Aggregate) – Test No. 34

Participants in this test were asked to prepare their own sample from the bags of bulk Granular A supplied. Seventy-eight laboratories reported results for this test in 2014. The test method requires reporting of control sample test results to demonstrate that the testing process is in control. This year, two of the participants reported control sample results outside the range established for the material. These two laboratories were manually

removed from the analyses and identified as outliers. In addition, three outliers were selected by the use of iterative technique.

LS-619 provides precision estimates for fine aggregates with the abrasion loss in the range of 7% to 18%. The coefficient of variation of 7.8% obtained in 2014 is consistent with the precision estimate of 7.6% published in LS-619 and the values (6.2% to 7.7%) reported in the past three years. However, the majority of the data points are located in the lower left and upper right quadrant of the scatter diagram indicating a strong laboratory bias.

3.4.18 LS-702 - Particle Size Analysis of Soil – Test Nos. 40-45

Participants in this test were instructed to submit the data sheets to demonstrate that the test was done according to LS-702. Based on the data sheets submitted, two of the laboratories did not perform the test in accordance with this test procedure and one of the participants did not submit data sheet. All three laboratories were manually removed from the analyses and identified as outliers. Eighty-eight laboratories participated in the hydrometer test in 2014. Eighty percent of the laboratories reported results ranging from 99.4% to 99.9% of material passing the 2.00 mm sieve. For this reason, the data for 2.0 mm sieve (Test No. 40) was also subjected to the statistical analysis using no outlier technique. This technique does not assign rating for individual test. As a result, no rating was assigned for 2.0 mm sieve and the results of the analysis are reported for information purpose only.

Outliers were selected using the iterative technique. The number of outliers identified by the use of iterative technique range from five for percent passing 425 µm and 20 µm to a maximum of seven for percent passing 5 µm and 2 µm. Successive scatter diagrams for this test show pronounced between laboratory biases. The standard deviations obtained in 2014 for all the particle sizes passing, except 2 µm, are slightly lower than that of the values reported in the past three years. The standard deviations obtained for the 2 µm size are slightly higher than the variations reported in the past three years. The laboratories that are identified as outliers should examine their equipment and technician's skills to ensure that they meet the requirements of the test procedure.

3.4.19 LS-703 and 704 - Atterberg Limits of Soil – Test Nos. 46-48

One hundred and eight laboratories reported results for Atterberg limit tests in 2014. Nine outliers for liquid limit (Test No. 46) and seven for plastic limit test (Test No. 47) were identified using the iterative technique. The scatter plots for both liquid and plastic limit tests as well as for plasticity index (Test No. 48) show strong laboratory bias. Both liquid and plastic limit tests require significant operator skills. Liquid limit test also requires good condition and calibration of the apparatus. Close attention to the condition and calibration of the liquid limit apparatus and employing skilled technicians may reduce the laboratory biases.

The material supplied for the soil tests in 2014 is a medium to high plastic clay (CI to CH) with liquid limit in the neighbourhood of 50 (LL = 50±). In view of this, the multi-laboratory variations (1s) published in the ASTM for high plastic clay (CH) with a liquid limit of 59.9

and plastic limit of 20.4 are used to evaluate the performance of the participants in the 2014 program. The standard deviations obtained for plastic limit and plasticity index are significantly lower than the values published in the ASTM precision statements (refer Appendix C) and for liquid limit test, standard deviations obtained are consistent with that of the precision estimate published in ASTM D 4318. However, the variations obtained for all three index tests in 2014 are noticeably higher than that of the values reported in the past three years.

3.4.20 LS-705 - Specific Gravity of Soils – Test No. 49

The participants were requested to perform this test according to LS-705. This test method requires that the test be performed on a minimum of three specimens, and the difference between the largest and smallest (i.e., range) specific gravity values of the test specimens determined is within 0.02. Further, it requires that the test be repeated if the range exceeds the specified limit. The laboratories that reported results with the range in excess of 0.02 appear to have difficulty in repeating the test within their testing environment. In 2014, two laboratories reported specific gravity values with the range in excess of the specified limit of 0.02 and two of the participants did not submit data sheet. All four laboratories were manually removed from the statistical analysis and identified as outliers.

Eighty-nine laboratories reported results for this test in 2014. In addition to the laboratories that were removed manually, three more outliers were identified using the critical value method. Ninety-three per cent of the data points are located in the first and third quadrants of the scatter diagram showing a pronounced between laboratory bias. Several steps in this test procedure can influence the results, particularly the equipment and method employed for preparation of the test specimen and removal of entrapped air from the test specimen. Laboratories finding themselves in this situation should carefully examine their equipment and procedure.

The standard deviation of 0.030 obtained in 2014 is slightly higher than the results reported in the 2012 and 2013 studies. LS-705 is similar to that of AASHTO T 100, which reports a multi-laboratory standard deviation of 0.04. As in the past three studies, the standard deviations obtained in 2014 are also found to be significantly lower than that of the precision estimate published in the AASHTO T 100.

3.5 SUPERPAVE CONSENSUS PROPERTY TESTS

3.5.1 LS-629 - Uncompacted Void Content of Fine Aggregate – Test No. 95

The participants were asked to perform the test in accordance with LS-629, using the fine aggregate prepared by splitting the material passing 4.75 mm sieve of the Granular A. This test method is a modified version of AASHTO T 304. LS-629 follows Method A of AASHTO T 304, except for the preparation of the test specimen to be used in the determination of bulk specific gravity of fine aggregates. The significant difference between the methods is that LS-629 requires the test specimens be washed on the 75 μm sieve until all the material finer than 75 μm is removed. In addition, LS-629 specifies that the bulk relative

density is determined using the graded sample and not the individual size fraction method described in Clause 9.4 of AASHTO T 304. In order to minimise the testing work, the participants were advised to use the bulk relative densities reported for fine aggregate determined in accordance with LS-605 under Test No. 27, to compute the uncompacted void contents of samples 3.14 and 4.14.

Sixty-four laboratories submitted results for this test in 2014. Two laboratories were identified as outliers using the iterative technique. Scatter diagram shows a combination of random variation and laboratory bias for some laboratories. The standard deviations of 0.48 and 0.60 obtained in 2014 are fairly consistent with the values obtained in the past three years. The standard deviations obtained for both samples are significantly higher than the value of 0.33% published in the ASTM precision statements for graded standard sand. The estimates of precision published in ASTM C 1252 are based on graded sand as described in ASTM C 778, which is considered rounded, and is graded from 600 µm to 150 µm. The type of material used for the development of precision statements in ASTM C 1252 may not be typical of the sand samples that were used in this testing program. The uncompacted void contents reported were calculated using the bulk relative densities that were determined by the individual laboratories. The use of the bulk relative densities determined by the individual laboratories further compounds the variations associated with the results reported for uncompacted void contents. ASTM C 1252 suggests that a difference in relative density of 0.05 will change the calculated void content by about one percent. The laboratories that are identified as outliers should review their test procedures and the skill of the technician.

3.5.2 ASTM D 2419 - Sand Equivalent Value of Fine Aggregate - Test No. 96

Participants were asked to prepare the fine aggregate sample for this test by splitting the Granular A material passing 4.75 mm sieve. Two alternate procedures for the preparation of test specimen (air-dry or pre-wet) are allowed in both ASTM and AASHTO methods. The participants were given the option of preparing the test specimen in accordance with either method.

Sixty-one laboratories reported results for this test in 2014. Two outliers were identified by the use of iterative technique. The lower left and upper right quadrants of the scatter diagram account for 82% of the points showing pronounced laboratory bias. The standard deviation of 4.9 obtained for both samples in 2014 is significantly lower than the values reported in the 2013 study and the multi-laboratory precision estimate of 8.0 published by ASTM for samples with sand equivalent value less than 80.

3.5.3 ASTM D 5821 - Percent of Fractured Particles – Test No. 97

The Granular A samples 1.14A and 2.14A supplied did not contain adequate amount of material retained on 19.0 mm sieve. For this reason, the participants were advised to perform the test only on coarse aggregate passing the 19.0 mm sieve.

ASTM D 5821 is very similar to MTO LS-607. Sixty-eight laboratories submitted results for this test in 2014. Four outliers were detected using the iterative technique. The scatter

diagram shows a combination of random variation and laboratory bias for some laboratories. The average means determined by the ASTM method (79.1%) and MTO version (76.4%) on the same aggregate samples differs only by 2.7%, which is significantly lower than the multi-laboratory variations published by ASTM (5.2%) and MTO LS-608 (4.7%). Further, the standard deviations (2.3 and 2.5) obtained in 2014 are significantly lower than the precision estimate of 5.2 published by ASTM. ASTM has not conducted inter-laboratory studies to determine a precision estimate and currently publishes statistical data provided by MTO. The variation obtained in 2014 is also noticeably lower than that of the values (4.3 to 6.4) reported in the past three years.

3.5.4 ASTM D 4791 - Percent Flat and Elongated Particles – Test No. 99

The coarse aggregate samples supplied did not contain adequate amount of material retained on the 19.0 mm sieve. For this reason, participants were advised to perform the test only on coarse aggregate passing the 19.0 mm sieve, using a ratio of 5:1 and to calculate the weighted average by assigning the same percent flat and elongated particles value as the next smaller fraction (i.e., 19.0 mm - 13.2 mm) for 26.5 mm to 19.0 mm that need not be tested.

Sixty-eight laboratories reported results for this test in 2014. Two outliers were detected using the iterative technique. The standard deviations of 0.61 and 0.65 obtained in 2014 are slightly lower than the values (0.78 to 0.80) reported in 2013. However, the average coefficient of variation of 56.0% obtained in 2014 is consistent with the value (55.2%) obtained in 2013 and significantly lower than the values reported in 2011(81.8%) and 2012 (64.5%). The majority of points on the scatter plot are located in the first and third quarter indicating significant laboratory bias.

ASTM D 4791 requires that the percent flat and elongated particles results are reported separately for each fraction tested. The precision estimates in this test method are also provided separately for each fraction ranging from 19.0 mm to 12.5 mm, 12.5 mm to 9.5 mm, and 9.5 mm to 4.75 mm. However, the results reported in this study are based on the weighted average calculated using the results of five fractions ranging from 26.5 mm to 4.75.mm. For this reason, a direct comparison of the multi-laboratory variations obtained in this study with that of the precision estimates published by ASTM is not possible.

4. Laboratory Rating System

The laboratory rating system assigns separate overall ratings for each category of laboratories, i.e., low complexity (Production) aggregate laboratories, high complexity (Full Service) Aggregate laboratories, Soil laboratories, and Superpave laboratories. Laboratories must participate in all of the tests that are listed under each category (i.e., Production, Full Service, Soil and Superpave) to assign an overall laboratory rating. Production (CCIL Type C) laboratories are required to carry out wash pass 75 μm, sieve analysis, percent crushed particles, percent asphalt coated particles, and percent flat and elongated particles tests. In addition to these tests, Full Service laboratories (CCIL Type D) must carry out micro-Deval (coarse and fine), freeze-thaw, and/or magnesium sulphate soundness, relative density and absorption (coarse and fine) tests. Soil laboratories are required to carry out particle size analysis, Atterberg limits, and specific gravity of soil tests. Superpave aggregate laboratories are required to perform all four consensus property tests (i.e. uncompacted void content, sand equivalent value, percent fractured particles, and flat and elongated particles).

The rating system gives a maximum rating of 10 for each test, (e.g. 5 for wash pass 75 μm on sample 1.14, plus -5 for wash pass 75 μm on sample 2.14, equals 10 (the negative sign indicating a test result less than the mean is ignored)). See Section 2.1 for explanation of test method ratings. Some tests that are normally reported together are averaged and given a maximum of 10. The relative density and absorption (coarse and fine), one-point Proctor values (maximum wet and dry density, and optimum moisture content), particle size analysis of soils, and Atterberg limits are treated in this manner. Because of the large number of individual test ratings in the sieve analysis results, the ratings are modified so as not to unduly bias the overall balance between various tests. The ratings for each sieve size are added and then divided by eleven coarse and fine sieves for which results were reported, and multiplied by 3 to give a laboratory rating with a maximum of 30 for this test. Individual laboratory ratings are calculated by adding the ratings of each test in the appropriate lab category (i.e. Production, Full Service, Soil, or Superpave) and converting the sum to a percentage of the maximum available rating for the category. The spread of laboratory ratings for Production, Full Service, Soil, and Superpave laboratories are given in the form of histograms in Figures 2 to 5. The rating system for "Full Service Laboratory" (Type D) shows that 55% of the participating laboratories in 2014 obtained a rating higher than 90 and, in the case of "Production Laboratory" (Type C), 45% of the participants obtained an overall laboratory rating higher than 90. The rating system for soil tests show 54% of the participants obtained an overall rating higher than 90, and in the case of consensus property tests (Superpave), 57% of the participants obtained an overall laboratory rating higher than 90. The laboratory rating system data is reported in the Appendices F1, F2, F3, and F4.

Laboratory ratings for each category are given to participants in the covering letter accompanying the individual laboratory results. A poor or good rating for a laboratory in one year is an indication of how that laboratory performed in the proficiency study, and may not be a reflection of how the laboratory performs year round. A consistently poor rating over two or more years may be cause for serious concern.

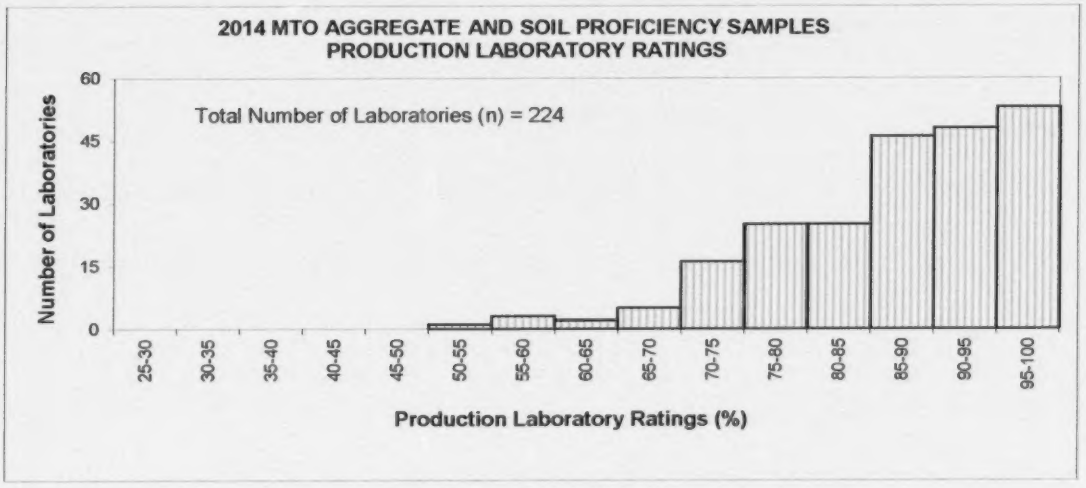


Figure 11. Production Laboratory Ratings

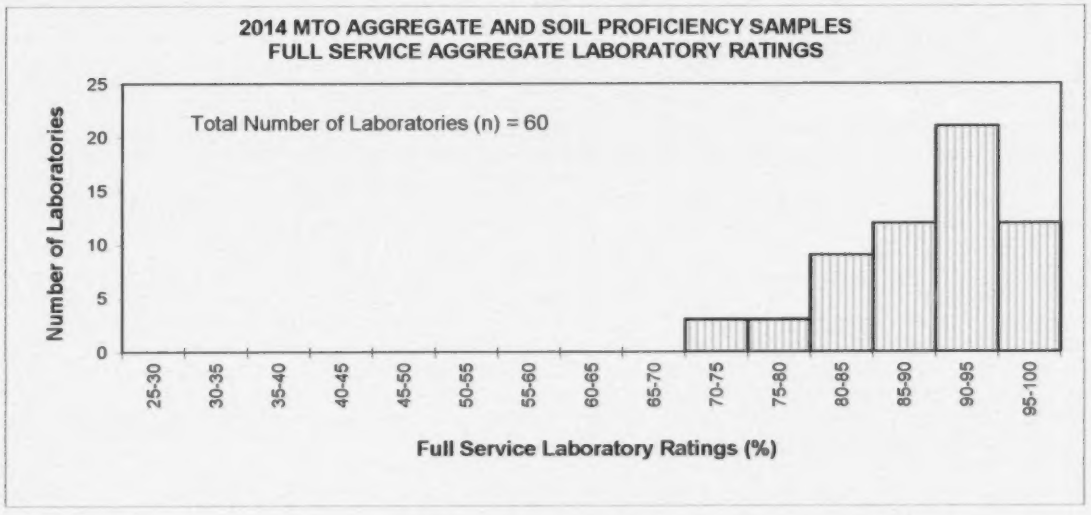


Figure 12. Full Service Laboratory Ratings

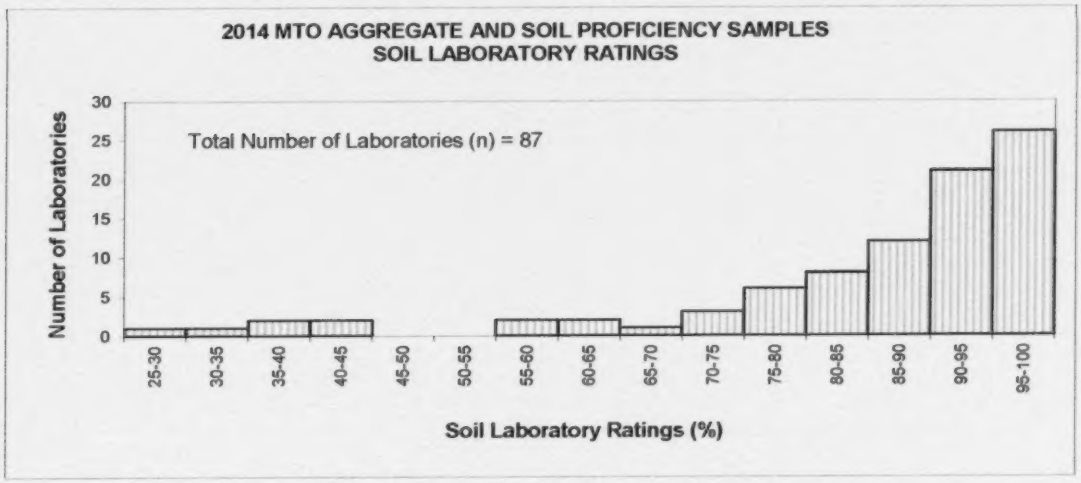


Figure 13. Soil Laboratory Ratings

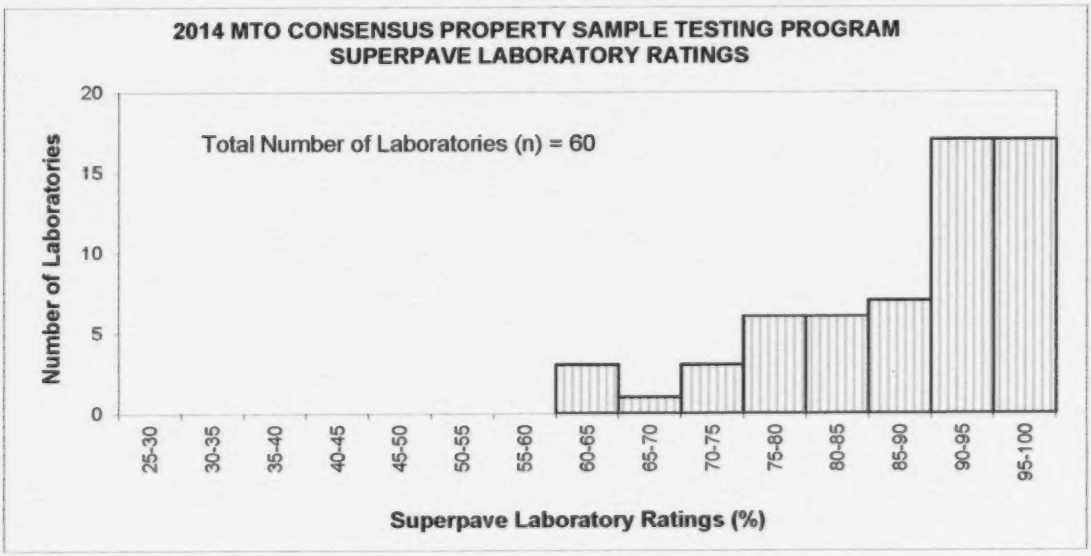


Figure 14. Superpave Laboratory Ratings

5. Conclusions

The method of proficiency sample preparation employed by MTO resulted in almost identical mean gradation values for samples 1.14 and 2.14. The differences in mean, as well as in the standard deviations between pairs of samples for both coarse and fine sieves are almost negligible. Based on the results, it may be concluded that the sample preparation method employed is very effective and capable of producing a uniform and nearly identical material at reasonable cost.

The majority of the aggregate and soil test results of the 2014 Aggregate and Soil Proficiency Sample Testing Program compare favourably with the results of previous studies. In some cases, the variations show noticeable improvement over previous years' results and the precision estimates of those tests where MTO or ASTM precision statements are available. The scatter diagrams for the majority of the aggregate tests show either random variation or a combination of random variation and laboratory bias for some laboratories.

Two hundred and thirty of the laboratories that participated in the aggregate tests are CCIL Type C (Production) certified, and sixty of those are also CCIL Type D (Full Service) certified. CCIL inspects the certified laboratories for quality control procedures, ability of technicians, and condition and calibration of the equipment at about eighteen month intervals. The performance of laboratories in most of the aggregate tests (Type C and Type D) is consistent with the results in the past and a large number of these tests show improvement in multi-laboratory variation over the established precision estimates. The improvements noted may be due to the on-site laboratory inspection by CCIL at regular intervals, proficiency sample testing, and due to an increased awareness of the importance of proper testing and quality control procedures implemented by CCIL.

Eighty-seven laboratories participated in all three soil tests. The variations found in 2014 for the soil tests are consistent with that of the values reported in the last three years' studies, but the scatter diagrams of all three tests still show strong laboratory biases. The results of soil tests are significantly influenced by operator skills, testing environment, and the condition and calibration of the equipment. Thirty-five of the Eighty-seven laboratories that participated in the soil tests are on the MTO Vendors List. Most of the laboratories that are on the MTO Vendors List were inspected by MTO staff more than eight to ten years ago and only a few re-inspections[8] have been done to date.

Sixty laboratories participated in all four Superpave consensus property tests. The results of 2014 compare favourably with the results of past three years. However, the multi-laboratory precisions obtained in 2014, except uncompacted void content, show improvement over the ASTM precision estimates. As in the past, the scatter diagrams for ASTM D 2419 and 4791 show strong laboratory biases. The quality control program implemented by CCIL is expected to bring about improvements in the multi-laboratory variations.

8 To arrange an inspection of your Soil Laboratory, please contact Mahabir Singh, Soils and Aggregates Section, Ministry of Transportation, phone (416) 235-6577, fax (416) 235-3919, Mahabir.Singh@ontario.ca.

6. Recommendations

Although, there are improvements in the multi-laboratory variations over the precision estimates established by ASTM and MTO, strong laboratory biases still remain in four of the aggregate tests, two of the consensus property test procedures, and all of the soil tests. The laboratories that were identified as outliers should examine their quality control practices, the condition and calibration of equipment, testing procedures, and skills of the technicians. Laboratories must investigate the causes and prepare corrective action reports as required by the quality system whenever a rating of 2 or less is obtained for each sample in a test.

The results of the 2014 MTO Aggregate and Soil Proficiency Sample Testing Program suggest that most laboratories have performed satisfactorily. Laboratories that obtained relatively low ratings must focus on quality control practices, operator training, standardization and calibration of equipment, and improvements to laboratory environment in order to improve their performance.

For all of the tests that were included in this study, the equipment to be used is regulated by the test method itself. A good state of equipment maintenance, repair, and correct calibration is required in order to achieve improvements. It is hoped that the mandatory Quality System implemented by CCIL will encourage laboratories to conduct a review of their internal quality control practices to ensure that they have the correct equipment and properly trained technicians. Laboratories will find that a well-documented and regular program of internal inspection, calibration, and testing of control or reference samples is beneficial to maintaining a high level of confidence in their results.

7. Acknowledgments

The authors would like to acknowledge Bob Gorman of the Soils and Aggregates Section for the selection of aggregate materials for the 2014 proficiency sample testing program. We would also like to thank the many laboratory staff, students and engineers-in-training of the Materials Engineering and Research Office for their dedicated assistance in preparing more than 2510 individual samples, from almost 50 tonnes of aggregate and soil material, for distribution to the program participants.

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Appendix A: Glossary of Terms

Acceptable difference between two results (difference two-sigma limit (d2s)) as an index of precision is the maximum acceptable difference between two results obtained on test portions of the same material tested by two different laboratories. The index, d2s, is the difference between two individual test results that would be equalled or exceeded in only one case in twenty in the normal and correct operation of the method. The index is calculated by multiplying the multi-laboratory standard deviation (1s) by the factor $2\sqrt{2}$ (2.83).

Accuracy refers to the degree of mutual agreement between a set of measurements with an accepted reference or 'true value'. This 'true' or reference value can be an assigned value arrived at by actual experiments.

Bias of a measurement process is a consistent and systematic difference between a set of test results derived from using the process and an accepted reference value of the property being measured. For the majority of aggregate and soil tests, there is no acceptable reference material, so bias is impossible to compute.

Coefficient of Variation expresses the standard deviation as a percentage of the mean, where:

$$C.V. = \frac{\text{std dev}}{\text{mean}} \times 100$$

Critical Value is that value of the sample criterion which would be exceeded by chance with some specified probability (significance level) on the assumption that all the observations did indeed constitute a random sample from a common system of causes.

MAIDB refers to Mineral Aggregate Inventory Data Bank of the Ministry of Transportation.

Median is synonymous with the middle and the **sample median** is the middle value of a list of test results when the observations are ordered from smallest to largest in magnitude. After rearranging the observations in increasing order (from most negative to most positive), the **sample median** is the *single middle value* in the ordered list, if n is odd, or the *average of the two middle values* in the ordered list, if n is even, where n equals the number of observations.

Multi-laboratory precision is a quantitative estimate of the variability of a large group of individual test results when each test has been made in a different laboratory and every effort has been made to make test portions of the material as nearly identical as possible. Under normal circumstances, the estimates of the one-sigma limit (1s) for multi-laboratory precision are usually larger than those for single-operator precision because different operators and different equipment are being used in different laboratories.

Outlier is a measurement that, for a specific degree of confidence, is not part of the population. In this study, an outlier is generally three or more standard deviations from the

mean, giving a confidence level of ninety-nine percent. If a laboratory test result is classified as an outlier, it means that something went wrong either with the sample or in the laboratory.

Precision refers to the degree of mutual agreement between individual measurements on the same material. In other words, precision is a measure of how well the individual test results of a series agree with each other.

Sample mean or average is the sum of all observations divided by the total number of observations.

Single operator precision (one-sigma limit (1s)) indicates the variability, as measured by the deviations above and below the average, of a large group of individual test results when the tests have been made on the same material by a single operator using the same apparatus in the same laboratory over a relatively short time.

Standard deviation is the most usual measure of the dispersion of observed values or results expressed as the positive square root of the variance.

Variance is a measure of the squared dispersion of observed values or measurements expressed as a function of the sum of the squared deviations from the population mean or sample average.

Appendix B1: List of Participants

2014 Participants List
Ministry of Transportation
Aggregate and Soil
Proficiency Sample
Testing Program

For further information on this program, contact:

Mark Vasavithasan (416) 235-4901, or
Stephen Senior (416) 235-3734

	LS-601 Wash Pass 75µm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-613 Insoluble Residue	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
A. L. Blair Construction Limited Moose Creek, ON Mr. Justin Blair Tel: 613 538-2271	✓	✓				✓	✓								✓				
AGS Associates Inc. Scarborough, ON Mr. Amjed Siddiqui Tel: 416 299-3655	✓	✓		✓	✓	✓	✓					✓	✓		✓	✓		✓	✓
Alston Associates Inc. Toronto, ON Mr. Demetra Matthews Tel: 905 474-5265	✓	✓				✓	✓								✓	✓	✓	✓	✓
AME - Materials Engineering Caledon, ON Mr. Scott Crowley Tel: 905 840-5914	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AME - Materials Engineering Ottawa, ON Mr. Harrison Smith Tel: 613 726-3039	✓	✓		✓	✓	✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
AME - Materials Engineering (24-165) Caledon, ON Mr. Scott Crowley Tel: 905 840-5914	✓	✓				✓	✓								✓	✓			
AME - Materials Engineering (24-270) Caledon, ON Mr. Scott Crowley Tel: 905 840-5914	✓	✓				✓	✓								✓	✓			
AME - Materials Engineering (24-271) Caledon, ON Mr. Scott Crowley Tel: 905 840-5914	✓	✓				✓	✓								✓	✓			
AME - Materials Engineering (24-297) Caledon, ON Mr. Scott Crowley Tel: 905 840-5914	✓	✓				✓	✓								✓	✓			
AME - Materials Engineering (24-298) Caledon, ON Mr. Scott Crowley Tel: 905 840-5914	✓	✓				✓	✓								✓	✓			
AME - Materials Engineering (24-384) Caledon, ON Mr. Scott Crowley Tel: 905 840-5914	✓	✓				✓	✓								✓	✓			
AME - Materials Engineering (24-911) Caledon, ON Mr. Scott Crowley Tel: 905 840-5914	✓	✓				✓	✓								✓	✓			
AME - Materials Engineering (24-912) Caledon, ON Mr. Scott Crowley Tel: 905 840-5914	✓	✓				✓	✓								✓	✓			
AMEC Earth & Environmental Ltd. Scarborough, ON Mr. S. Baskaran Tel: 416 751-6565	✓	✓		✓	✓	✓	✓				✓	✓	✓		✓	✓	✓	✓	✓

2014 Participants List

Ministry of Transportation

Aggregate and Soil

Proficiency Sample

Testing Program

For further information on this program, contact:

Mark Vasavithasan (416) 235-4901, or
Stephen Senior (416) 235-3734

	LS-601 Wash Pass 75µm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-613 Insoluble Residue	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
AMEC Earth & Environmental Ltd. Hamilton, ON Mr. Ognienko Lazic Tel: 905 312-0700	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
AMEC Earth & Environmental Ltd. Cambridge, ON Ms. Tammy Hawkins Tel: 519 650-7116	✓	✓		✓		✓	✓					✓	✓		✓	✓	✓	✓	✓
AMEC Earth & Environmental Ltd. Sarnia, ON Mr. Geoff Collier Tel: 519 337-5409	✓	✓				✓	✓								✓	✓			
AMEC Earth & Environmental Ltd. Tecumseh, ON Mr. Justin Palmer Tel: 519 735-2499	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
AMEC Earth & Environmental Ltd. Thorold, ON Mr. Andrew Markov Tel: 905 687-6616	✓	✓				✓	✓								✓	✓	✓	✓	✓
AMEC Earth & Environmental Ltd. – PN2 Hamilton, ON Ms. Amy McCulloch Tel: 905 312-0700								✓	✓										
AMEC Earth & Environmental Ltd. – PN4 Hamilton, ON Mr. Jesse Stickles Tel: 905 312-0700								✓	✓										
AMEC Earth & Environmental Ltd. – PN5 Hamilton, ON Ms. Heather Racher Tel: 905 312-0700								✓	✓										
Bernt Gilbertson Enterprises Ltd. Richards Landing, ON Mr. Scott Eddy Tel: 705 246-2076	✓	✓				✓	✓								✓				
BOT Construction Oakville, ON Mr. Vicks Sellathurai Tel: 905 827-3250	✓	✓		✓	✓	✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
BOT Construction - Mobile Oakville, ON Mr. Vicks Sellathurai Tel: 905 827-3250	✓	✓				✓	✓								✓	✓			
Bruno's Contracting (Thunder Bay) Ltd. Thunder Bay, ON Mr. Dante DiGregorio Tel: 807 623-1855	✓	✓				✓	✓								✓	✓			
C. Villeneuve Construction – Mobile 1 Hearst, ON Mr. Charles Harris Tel: 705 372-1838	✓	✓				✓	✓								✓	✓			
C. Villeneuve Construction – Mobile 2 Hearst, ON Mr. Charles Harris Tel: 705 372-1838	✓	✓				✓	✓								✓	✓			
C. Villeneuve Construction – Mobile 25 Hearst, ON Mr. Charles Harris Tel: 705 372-1838	✓	✓				✓	✓								✓	✓			
C.T. Soil & Materials Testing Inc. Windsor, ON Mr. Thomas O'Dwyer Tel: 519 966-8863	✓	✓		✓	✓	✓	✓				✓	✓	✓		✓	✓			
Caledon Sand & Gravel Ltd. Bolton, ON Mr. Leigh Mugford Tel: 519 927-5224	✓	✓				✓	✓								✓				

2014 Participants List

Ministry of Transportation

Aggregate and Soil

Proficiency Sample

Testing Program

For further information on this program, contact:

Mark Vasavithasan (416) 235-4901, or
Stephen Senior (416) 235-3734

	LS-601 Wash Pass 75µm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-613 Insoluble Residue	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
Cambium Inc. Peterborough, ON Mr. Wayne Rayfuse Tel: 705 741-4109	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓		✓	✓	✓	✓	✓
Capital Paving Inc. Guelph, ON Mr. Mark Latyn Tel: 519 822-4511	✓	✓				✓	✓								✓	✓			
CBM Aggregates Cambridge, ON Mr. Michael Smith Tel: 519 239-4743	✓	✓				✓	✓								✓				
CBM Aggregates Brighton, ON Mr. Michael Smith Tel: 519 922-1532	✓	✓				✓	✓								✓				
CBM Aggregates London, ON Mr. Michael Smith Tel: 519 240-8410	✓	✓				✓	✓								✓				
CBM Aggregates Sunderland, ON Mr. Michael Smith Tel: 705 879-2797	✓	✓				✓	✓								✓				
CBM Aggregates Westwood, ON Mr. Michael Smith Tel: 705 930-2826	✓	✓				✓	✓					✓	✓		✓				
CCI Group Inc. Concord, ON Ms. Liliana Fevga Tel: 905 856-5200	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Chung & Vander Dollen Engineering Limited, Kitchener, ON Mr. William Evans Tel: 519 742-8979	✓	✓		✓	✓	✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
CMT Engineering Inc. St. Clements, ON Mr. Nathan Love Tel: 519 699-5775	✓	✓				✓	✓								✓	✓			
COCO Paving Inc. Belleville, ON Mr. Michael Haisma Tel: 613 962-3461	✓	✓		✓		✓	✓				✓	✓	✓		✓	✓		✓	
COCO Paving Inc. Toronto, ON Mr. Oussama Ibrahim Tel: 416 346-5244	✓	✓		✓		✓	✓								✓				
COCO Paving Inc. Windsor, ON Mr. Ishaq Syed Tel: 519 999-1840	✓	✓		✓		✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
Coffey Geotechnics Inc. Toronto, ON Mr. Savio De Souza Tel: 416 213-1255	✓	✓				✓	✓								✓	✓	✓	✓	✓
Colacem Canada L'Original, ON Mr. Shu Yang Tel: 819 242-4312	✓	✓				✓	✓					✓	✓		✓				
Concrete Materials Lab, Dept. of Engineering, U. of Toronto Dr. R. D. Hooton Tel: 416 946-5496														✓					
Construction Testing Asphalt Lab Ltd. Cambridge, ON Mr. Peter Lung Tel: 519 622-7023	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

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Cornwall Gravel Company Limited Cornwall, ON Ms. Billie-Gail Macfarlane Tel: 613 930-3530	✓	✓		✓	✓	✓	✓				✓	✓	✓		✓	✓		✓	
Corporation of the County of Grey Chatsworth, ON Mr. Gregory Pell Tel: 519 376-7339	✓	✓				✓	✓								✓				
Cox Construction Limited Guelph, ON Mr. Alana Smith Tel: 519 240-9071	✓	✓		✓		✓	✓								✓	✓			
Cruickshank Construction Ltd. Kingston, ON Mr. Tim Bilton Tel: 613 536-9112	✓	✓		✓	✓	✓	✓					✓	✓		✓				
Cruickshank Construction Ltd. - Mobile Kingston, ON Mr. Tim Bilton Tel: 613 258-9112	✓	✓				✓	✓								✓				
D. Crupi & Sons Limited Toronto, ON Mr. P.Kandasaami T el: 416 677-3037	✓	✓		✓		✓	✓								✓				
D. F. Elliott Consulting Engineering New Liskeard, ON Mr. Brad Gilbert Tel: 705 647-6871	✓	✓				✓	✓								✓	✓			
Danford Construction Madoc, ON Mr. Al Danford Tel: 613 473-2468	✓	✓				✓	✓								✓				
Davroc Testing Laboratories Inc. Brampton, ON Mr. Sal Fasullo Tel: 905 792-7792	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
DBA Engineering Limited Cambridge, ON Mr. Andy Burleigh Tel: 519 622-0090	✓	✓				✓	✓								✓	✓			
DBA Engineering Limited Vaughan, ON Mr. Zlatko Brcic Tel: 905 851-0090	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
DBA Engineering Limited – PN3 Vaughan, ON Mr. Alhua Liang Tel: 905 851-0090								✓											
DBA Engineering Limited – PN4 Vaughan, ON Mr. Kevin Jackson Tel: 905 851-0090								✓											
DBA Engineering Ltd. Kingston, ON Mr. Mark McClelland Tel: 613 389-1781	✓	✓		✓	✓	✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
Department of Civil Engineering Ryerson University, Toronto Dr. Medhat Shehata Tel: 416 979-5000														✓					
District Municipality of Muskoka Bracebridge, ON Mr. Dave Wood Tel: 705 645-6764	✓	✓				✓	✓								✓	✓	✓	✓	
Drain Bros Excavating Ltd. Norwood, ON Mr. Elton Neuman Tel: 705 639-2301	✓	✓				✓	✓					✓	✓		✓	✓			

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Stephen Senior (416) 235-3734

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DST Consulting Engineers Inc. Kenora, ON Mr. Neil Johnson Tel: 807 548-2383	✓	✓				✓	✓								✓	✓			
DST Consulting Engineers Inc. Thunder Bay, ON Dr. Myint Win Bo Tel: 807 623-2929	✓	✓	✓	✓		✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
DST Consulting Engineers Inc. Ottawa, ON Mr. George Thomas Tel: 613 748-1415	✓	✓				✓	✓								✓				
Dufferin Aggregates Acton, ON Ms. Kelly Mercer Tel: 416 453-3268	✓	✓				✓	✓								✓				
Dufferin Aggregates Cambridge, ON Mr. Gord Taylor Tel: 905 308-5324	✓	✓				✓	✓								✓				
Dufferin Aggregates Cayuga, ON Mr. Gord Taylor Tel: 905 308-5324	✓	✓		✓		✓	✓				✓	✓	✓		✓				
Dufferin Aggregates Dundas, ON Mr. Gord Taylor Tel: 905 308-5324	✓	✓				✓	✓								✓				
Dufferin Aggregates Milton, ON Ms. Kelly Mercer Tel: 416 453-3268	✓	✓				✓	✓								✓				
Dufferin Aggregates Orono, ON Ms. Kelly Mercer Tel: 416 453-3268	✓	✓				✓	✓								✓				
Dufferin Aggregates Brechin, ON Ms. Kelly Mercer Tel: 416 453-3268	✓	✓				✓	✓								✓			✓	
Dufferin Aggregates Cambridge, ON Mr. Gord Taylor Tel: 905 308-5324	✓	✓				✓	✓								✓				
Dufferin Construction Ltd. (QC) Oakville, ON Mr. Ronald Abdul Tel: 416 891-0597	✓	✓		✓		✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
Dufferin Construction Ltd. (QC) - London Oakville, ON Mr. Ronald Abdul Tel: 416 891-0597	✓	✓				✓	✓								✓				
Dufferin Construction Ltd. (QC) - Mobile 1 Oakville, ON Mr. Ronald Abdul Tel: 416 891-0597	✓	✓				✓	✓								✓				
Dufferin Construction Ltd. (QC) - Mobile 3 Oakville, ON Mr. Ronald Abdul Tel: 416 891-0597	✓	✓				✓	✓								✓				
Duncor Enterprises Inc. Barrie, ON Mr. Peter Smith Tel: 705 730-1999	✓	✓				✓	✓								✓				
E.C. King Contracting Owen Sound, ON Mr. Lance Elliott Tel: 519 376-6140	✓	✓				✓	✓								✓	✓			

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Mark Vasavithasan (416) 235-4901, or
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	LS-601 Wash Pass 75µm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-613 Insoluble Residue	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
Engtec Consulting Inc. Vaughan, ON Mr. Salman Bhutta Tel: 905 856-2988	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓
Esko Savela & Son Contracting Inc. Shuniah, ON Mr. Craig Baumenn Tel: 807 983-2097	✓	✓				✓	✓								✓				
exp Services Inc. Timmins, ON Mr. Jason Ferrigan Tel: 705 268-4351	✓	✓				✓	✓								✓				
exp Services Inc. Brampton, ON Mr. Ammanuel Yousif Tel: 905 793-9800	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
exp Services Inc. London, ON Mr. David Speller Tel: 519 963-3000	✓	✓				✓	✓	✓			✓	✓	✓		✓	✓	✓	✓	✓
exp Services Inc. Oldcastle, ON Mr. David Speller Tel: 519 737-0588	✓	✓				✓	✓								✓	✓			
exp Services Inc. Hamilton, ON Mr. Ashraf Abass Tel: 905 573-4000	✓	✓				✓	✓								✓	✓	✓	✓	✓
exp Services Inc. Sudbury, ON Mr. Rob Ferguson Tel: 705 674-9681	✓	✓		✓		✓	✓	✓			✓	✓	✓		✓	✓	✓	✓	✓
exp Services Inc. Ottawa, ON Mr. Ismail M. Taki Tel: 613 723-2886	✓	✓		✓	✓	✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
exp Services Inc. Thunder Bay, ON Mr. Darryl Kelly Tel: 807 623-9495	✓	✓		✓		✓	✓				✓	✓	✓		✓	✓		✓	
exp Services Inc. Barrie, ON Mr. Leigh Knegt Tel: 705 734-6222	✓	✓				✓	✓								✓	✓	✓	✓	✓
Fermar Construction Limited Rexdale, ON Mr. Ramon Meza Tel: 416 436-6309	✓	✓		✓		✓	✓								✓	✓			
Fowler Construction Company Bracebridge, ON Mr. Ross Elliott Tel: 705 644-4037	✓	✓		✓		✓	✓					✓	✓		✓	✓			
Fowler Construction Company – Mobile Bracebridge, ON Mr. Ross Elliott Tel: 705 644-4037	✓	✓		✓		✓	✓								✓	✓			
G. Tackaberry & Sons Construction Co. Ltd., Athens, ON Mr. Paul Rodgers Tel: 613 924-2634	✓	✓				✓	✓								✓	✓			
Gazzola Paving Ltd. Etobicoke, ON Mr.Solomon Andualem Tel: 416 675-9803	✓	✓				✓	✓								✓				
Geo Terre Limited Brampton, ON Mr. Julian Murillo Tel: 905 455-5666	✓	✓				✓	✓								✓	✓	✓	✓	✓

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Geo-Logic Inc. Peterborough, ON Mr. Matt Rawlings Tel: 705 749-3317	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Geo-Logic Inc. Oshawa, ON Mr. Vincent Zappia Tel: 905 728-1500	✓	✓				✓	✓								✓	✓	✓	✓	✓
Geo-Logic Inc. Pembroke, ON Mr. Sheldon Thomas Tel: 613 735-8361	✓	✓				✓	✓								✓	✓	✓	✓	✓
GM BluePlan Engineering Limited Owen Sound, ON Mr. Derek Brewster Tel: 519 376-1805	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Golder Associates Ltd. Barrie, ON Mr. Nick Laposta Tel: 705 722-4492	✓	✓				✓	✓								✓	✓	✓	✓	✓
Golder Associates Ltd. Cambridge, ON Mr. Jodi Norris Tel: 519 620-1222	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Golder Associates Ltd. Markham, ON Mr. Albert Lam Tel: 905 475-5591	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Golder Associates Ltd. London, ON Mr. Chris Sewell Tel: 519 652-0099	✓	✓		✓		✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
Golder Associates Ltd. Mississauga, ON Ms.Mariana Manojlovic Tel: 905 567-6100	✓	✓				✓	✓								✓	✓	✓	✓	✓
Golder Associates Ltd. Ottawa, ON Mr. Chris Mangione Tel: 613 592-9600	✓	✓		✓		✓	✓	✓							✓	✓	✓	✓	✓
Golder Associates Ltd. Sudbury, ON Ms. Sylvie LaPorte Tel: 705 524-6861	✓	✓		✓		✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
Golder Associates Ltd. Whitby, ON Mr. Jeremy Rose Tel: 905 723-2727	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Golder Associates Ltd. Windsor, ON Mr. Roy Walsh Tel: 519 250-3733	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Golder Associates Ltd. Burnaby, B.C. Ms. Lily Hu Tel: 604 412-6899	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Golder Associates Ltd. – PN3 Burnaby, B.C. Mr. Ben Hudson Tel: 604 412-6899							✓												
Graham Brothers Construction Limited Brampton, ON Mr. Greg Thompson Tel: 905 866-3093	✓	✓		✓		✓	✓					✓	✓		✓	✓		✓	
Greenwood Aggregates Amaranth, ON Mr. Andrew Raymond Tel: 519 941-0732	✓	✓		✓		✓	✓					✓	✓		✓			✓	

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H & H Construction Inc. Petawawa, ON Mr. Kevin Hoffman Tel: 613 687-8154	✓	✓				✓	✓								✓				
Harold Sutherland Construction Ltd. Kemble, ON Mr. Roland Leigh Tel: 519 376-3506	✓	✓		✓		✓	✓				✓	✓	✓		✓	✓			
HATCH Ltd. Niagara Falls, ON Mr. Ralph Serluca Tel: 905 374-5200	✓	✓				✓	✓								✓	✓	✓	✓	✓
Holcim Canada Inc. Etobicoke, ON Mr.G. Julio-Betancourt Tel: 416 744-2206	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓	✓	✓			✓	
Houle Chevrier Engineering Limited Carp, ON Mrs. Krystle Smith Tel: 613 836-1422	✓	✓		✓		✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
Huron Construction Co. Ltd. Chatham, ON Mr. David Smith Tel: 519 354-0170	✓	✓				✓	✓								✓				
Inspec-sol Inc. St. Catharines, ON Mr. Wayne Russell Tel: 905 682-0510	✓	✓				✓	✓								✓	✓	✓	✓	✓
Inspec-sol Inc. Kingston, ON Mr. Matt Storms Tel: 613 389-9812	✓	✓				✓	✓								✓	✓			
Inspec-Sol Inc. Mississauga, ON Mr. Karl Roechner Tel: 905 712-4771	✓	✓				✓	✓								✓	✓	✓	✓	✓
Inspec-sol Inc. Ottawa, ON Mr. Eric Bennett Tel: 613 727-0895	✓	✓				✓	✓								✓	✓			
Inspec-Sol Inc. Waterloo, ON Mr. Abdul H. Khan Tel: 519 725-9328	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Interpaving Asphalt & Aggregate Supply Ltd. Sudbury, ON Ms. Ashley Edwards Tel: 705 694-6210	✓	✓		✓		✓	✓	✓				✓	✓		✓	✓		✓	
Intratech Engineering Laboratories Inc. Scarborough, ON Mr. Frank Miles Tel: 416 754-2077	✓	✓		✓	✓	✓	✓				✓				✓	✓	✓	✓	✓
J & P Leveque Bros. Ltd. - Mobile 616 Bancroft, ON Mr. Shawn Fransky Tel: 613 332-5533	✓	✓				✓	✓					✓	✓		✓	✓		✓	
J & P Leveque Bros. Ltd. – Mobile 617 Bancroft, ON Mr. Shawn Fransky Tel: 613 332-5533	✓	✓				✓	✓					✓	✓		✓	✓		✓	
John D. Paterson & Associates Ottawa, ON Mr. Stephen Walker Tel: 613 226-7381	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓
John D. Paterson & Associates North Bay, ON Mr. Shawn Nelson Tel: 707 472-5331	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓

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K. J. Beamish Construction - Mobile 1 King City, ON Mr. Chad Henderson Tel: 905 833-4666	✓	✓				✓	✓								✓	✓			
K. J. Beamish Construction - Mobile 2 King City, ON Mr. Chad Henderson Tel: 905 833-4666	✓	✓				✓	✓								✓	✓			
K.J. Beamish Construction King City, ON Mr. Chad Henderson Tel: 905 833-4666	✓	✓		✓		✓	✓	✓			✓	✓	✓		✓	✓		✓	
Lafarge Canada Orono, ON Mr. Frances Clements Tel: 905 983-9260	✓	✓				✓	✓								✓				
Lafarge Canada – Mobile 434 Dundas, ON Mr. Chris Thomas Tel: 905 977-7363	✓	✓				✓	✓								✓				
Lafarge Canada - Orillia Lab Dundas, ON Mr. Chris Thomas Tel: 905 977-7363	✓	✓				✓	✓								✓				
Lafarge Canada Inc. Brechin, ON Ms. Christine Crumbie Tel: 705 484-5225	✓	✓				✓	✓					✓	✓		✓				
Lafarge Canada Inc. Dundas, ON Mr. Chris Thomas Tel: 905 977-7363	✓	✓		✓	✓	✓	✓				✓	✓	✓	✓	✓	✓		✓	
Lafarge Canada Inc. London, ON Ms. Kaitlyn Souter Tel: 519 537-0999	✓	✓				✓	✓								✓				
Lafarge Canada Inc. Cambridge, ON Mr. Michael Koch Tel: 905 979-3107	✓	✓				✓	✓								✓				
Lafarge Canada Inc. Fonthill, ON Mr. Michael Koch Tel: 905 979-3107	✓	✓				✓	✓								✓				
Lafarge Canada Inc. Hamilton, ON Mr. Michael Koch Tel: 905 979-3107	✓	✓		✓	✓	✓	✓				✓	✓	✓	✓	✓			✓	
Lafarge Canada Inc. Paris, ON Mr. Michael Koch Tel: 905 979-3107	✓	✓				✓	✓								✓				
Lafarge Canada Inc. Meldrum Bay, ON Mr. Jeff Middleton Tel: 705 283-3011	✓	✓				✓	✓								✓				
Lafarge Canada Inc. Ottawa, ON Mr. Fred Douglas Tel: 613 834-4223	✓	✓		✓	✓	✓	✓				✓	✓	✓		✓	✓		✓	
Lafarge Canada Inc. Stouffville, ON Ms. Christine Crumbie Tel: 905 640-5883	✓	✓				✓	✓								✓				
Lafarge Canada Inc. Caledon, ON Mr. Chris Thomas Tel: 905 977-7363	✓	✓				✓	✓								✓				

2014 Participants List

Ministry of Transportation

Aggregate and Soil

Proficiency Sample

Testing Program

For further information on this program, contact:

Mark Vasavithasan (416) 235-4901, or
Stephen Senior (416) 235-3734

	LS-601 Wash Pass 75µm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-613 Insoluble Residue	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
Lafarge Canada Inc. – Pt. Anne Quarry Belleville, ON Mr. Jason Malcolm Tel: 613 813-4857	✓	✓				✓	✓								✓				
Lafarge Construction Materials Ltd. Brockville, ON Mr. Paul Arkeveld Tel: 613 349-7422	✓	✓				✓	✓				✓	✓	✓		✓				
Lafarge Construction Materials Ltd. Glenburnie, ON Mr. Paul Arkeveld Tel: 613 349-7422	✓	✓				✓	✓								✓				
Landtek Limited Hamilton, ON Mr. Ralph Di Cienzo Tel: 905 383-3733	✓	✓		✓		✓	✓					✓	✓		✓	✓	✓	✓	✓
Lavis Contracting Co. Limited Clinton, ON Mr. George Brown Tel: 519 482-3694	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓		✓	✓		✓	
Law Engineering (London) Inc. London, ON Mr. Joe Law Tel: 519 680-9991	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓		✓	✓	✓	✓	✓
LVM Inc. Kitchener, ON Mr. Jason Taylor Tel: 519 741-1313	✓	✓		✓		✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
LVM Inc. Brantford, ON Ms. Lisa Roberts Tel: 519 720-0078	✓	✓				✓	✓								✓	✓	✓	✓	✓
LVM Inc. London, ON Ms. Amy Helle Tel: 519 685-6400	✓	✓				✓	✓								✓	✓	✓	✓	✓
LVM Inc. Stratford, ON Ms. Vicki Gravelle Tel: 519 273-0101	✓	✓				✓	✓								✓	✓	✓	✓	✓
LVM Inc. Toronto, ON Mr. Dawit Amar Tel: 416 213-1060	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
LVM/Merlex North Bay, ON Mr. J. P. Duhaime Tel: 705 476-2550	✓	✓				✓	✓								✓	✓	✓	✓	✓
McAsphalt Engineering Services Toronto, ON Mr. Michael Esenwa Tel: 416 281-8181	✓	✓		✓		✓	✓								✓	✓			
Mill-Am Corporation - Mobile 890901 Oldcastle, ON Mr. Cesare Di Cesare Tel: 519 945-7441	✓	✓				✓	✓								✓	✓			
Miller Northwest Limited – Mobile 120601 Dryden, ON Ms. Melodie Asselin Tel: 807 223-2844	✓	✓		✓		✓	✓								✓	✓			
Miller Northwest Limited - Mobile 942012 Dryden, ON Ms. Melodie Asselin Tel: 807 223-2844	✓	✓		✓		✓	✓								✓	✓			
Miller Paving Limited Markham, ON Ms. Carla Hariprashad Tel: 416 791-3408	✓	✓		✓	✓	✓	✓				✓	✓	✓		✓	✓		✓	

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Stephen Senior (416) 235-3734

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Miller Paving Limited Whitby, ON Ms. Carla Hariprashad Tel: 905 655-3889	✓	✓				✓	✓								✓				
Miller Paving Limited - Carden Lab Brechin, ON Ms. Christina Watts Tel: 705 484-1101	✓	✓				✓	✓								✓				
Miller Paving Limited – Carden Mobile Brechin, ON Ms. Christina Watts Tel: 705 877-8423	✓	✓				✓	✓								✓				
Miller Paving Limited - Mobile 8661 North Bay, ON Mr. Herb Villneff Tel: 705 472-3312	✓	✓				✓	✓								✓	✓			
Miller Paving Limited - Patterson Quarry Brechin, ON Ms. Christina Watts Tel: 705 385-0249	✓	✓				✓	✓								✓				
Miller Paving Ltd. – Mobile 60853 North Bay, ON Mr. Herb Villneff Tel: 705 472-3312	✓	✓				✓	✓								✓	✓			
Miller Paving Ltd. – Mobile 8660 Arnprior, ON Ms.Michelle Baumhour Tel: 613 623-3144	✓	✓				✓	✓								✓	✓			
Miller Paving Northern - Mobile 1084 North Bay, ON Mr. Herb Villneff Tel: 705 472-3312	✓	✓		✓		✓	✓								✓	✓			
Miller Paving Northern - Mobile 1254 North Bay, ON Mr. Herb Villneff Tel: 705 472-3312	✓	✓		✓		✓	✓					✓	✓		✓	✓			
Miller Paving Northern - Mobile 50612 Arnprior, ON Mr. Joshua Hodges Tel: 613 222-8045	✓	✓				✓	✓								✓	✓			
Miller Paving Northern - Mobile 60889 North Bay, ON Mr. Herb Villneff Tel: 705 472-3312	✓	✓				✓	✓								✓	✓			
Ministry of Transportation Downsview, ON Mr. Stephen Senior Tel: 416 235-3734	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ministry of Transportation – PN1 Downsview, ON Mr. Kliton Verli Tel: 416 235-3697								✓											
Ministry of Transportation – PN2 Downsview, ON Mr. Alex Prifti Tel: 416 235-4606								✓											
MNA Engineering Limited Scarborough, ON Mr. Peter Balendran Tel: 416 757-8882	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Nasiruddin Engineering Limited Mississauga, ON Mr.Shakeel Nasiruddin Tel: 905 565-9595	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Nelson Aggregate Co. Beamsville, ON Mr. Shawn Warkholdt Tel: 905 563-8226	✓	✓				✓	✓								✓				

2014 Participants List

Ministry of Transportation
Aggregate and Soil
Proficiency Sample
Testing Program

For further information on this program, contact:

Mark Vasavithasan (416) 235-4901, or
Stephen Senior (416) 235-3734

	LS-601 Wash Pass 75µm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-613 Insoluble Residue	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
Nelson Aggregate Co. Burlington, ON Mr. Michael Rook Tel: 905 335-5250	✓	✓				✓	✓								✓				
Nelson Aggregate Co. Orillia, ON Mr. Chris Roote Tel: 705 352-2264	✓	✓				✓	✓								✓				
Peto MacCallum Limited Barrie, ON Mr. Andrew Jones Tel: 705 734-3900	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Peto MacCallum Limited Hamilton, ON Mr. Amjad Khan Tel: 905 561-2231	✓	✓		✓	✓	✓	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓
Peto MacCallum Limited Kitchener, ON Mr. Tony Smith Tel: 519 893-7500	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
Peto MacCallum Limited Toronto, ON Mr. Geoffrey Uwimana Tel: 416 785-5110	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Pinchin Environmental Sault Ste. Marie, ON Mr. Wesley Tabaczuk Tel: 705 575-9207	✓	✓				✓	✓								✓	✓	✓	✓	✓
Pioneer Construction Inc. Sault Ste. Marie, ON Mrs. Shelley Geiling Tel: 705 541-2280	✓	✓		✓		✓	✓				✓	✓	✓		✓	✓			
Pioneer Construction Inc. Copper Cliff, ON Mr. David Pilkey Tel: 705 693-1363	✓	✓		✓		✓	✓	✓			✓	✓	✓		✓	✓			
Pioneer Construction Inc. Thunder Bay, ON Mr. Tony Fazio Tel: 807 768-6008	✓	✓		✓		✓	✓								✓	✓			
Port Colborne Quarries Inc. Port Colborne, ON Mr. Tim Cassibo Tel: 905 834-3647	✓	✓				✓	✓								✓				
Preston Sand & Gravel Kitchener, ON Mr. Matthew Bell Tel: 519 242-0902	✓	✓				✓	✓								✓				
R. W. Tomlinson Limited Ottawa, ON Mr. Paul Charbonneau Tel: 613 822-0543	✓	✓		✓		✓	✓				✓	✓	✓		✓	✓		✓	✓
R.S Wilson Materials Testing & Inspection Sault Ste. Marie, ON Mr. Robert Wilson Tel: 705 759-2881	✓	✓				✓	✓								✓	✓			
Regional Municipality of Durham Whitby, ON Mr. Joeman Ng Tel: 905 655-3344	✓	✓				✓	✓								✓	✓			
Sarafinchin Associates Limited Rexdale, ON Mr. Scott Jeffrey Tel: 416 674-1770	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Shaba Testing Services Limited Kirkland Lake, ON Mr. Lad Shaba Tel: 705 567-4187	✓	✓				✓	✓								✓	✓			

2014 Participants List

Ministry of Transportation

Aggregate and Soil

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Testing Program

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Mark Vasavithasan (416) 235-4901, or
Stephen Senior (416) 235-3734

	LS-601 Wash Pass 75µm	LS-602 Sieve Analysis	LS-603 Los Angeles Abrasion	LS-604/5 Relative Density	LS-606 Sulphate Soundness	LS-607 Percent Crushed Particles	LS-608 Percent Flat and Elongated	LS-609 Petrographic Number - Concrete	LS-616 Petrographic Analysis – Fine	LS-613 Insoluble Residue	LS-614 Freeze-Thaw	LS-618 Micro-Deval CA	LS-619 Micro-Deval FA	LS-620 Accelerated Mortar Bar	LS-621 Asphalt Coated Particles	LS- 623 One Point Proctor Density	LS-702 Particle Size Analysis	LS-703/4 Atterberg Limits	LS-705 Specific Gravity of Soils
Smelter Bay Aggregates Inc. Thessalon, ON Mr. Jacob King Tel: 705 842-2597	✓	✓				✓	✓								✓				
Soil Engineers Limited Scarborough, ON Mr. S. Sanjeevan Tel: 416 754-8515	✓	✓				✓	✓								✓	✓	✓	✓	✓
Soil Probe Ltd. Scarborough, ON Mr. K. Ilampooranan Tel: 416 754-7055	✓	✓				✓	✓								✓	✓			
SPL Consultants Limited Markham, ON Mr. Jordan Gadjanov Tel: 905 475-0065	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
SPL Consultants Limited Nepean, ON Mr. Chris Hendry Tel: 613 228-0065	✓	✓				✓	✓								✓	✓	✓	✓	✓
SPL Consultants Limited Vaughan, ON Mr. Andrew Mendonca Tel: 905 856-0065	✓	✓				✓	✓								✓	✓	✓	✓	✓
St Lawrence Testing & Inspection Co. Ltd. Cornwall, ON Mr. Gib McIntee Tel: 613 938-2521	✓	✓		✓		✓	✓				✓	✓	✓		✓	✓	✓	✓	✓
St. Marys Leaside Lab Toronto, ON Mr. Stephen Parkes Tel: 416 423-2439	✓	✓		✓	✓	✓	✓				✓	✓	✓	✓	✓				
Stantec Consulting Limited Ottawa, ON Mr. Jeff Weng Tel: 613 738-6075	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Stantec Consulting Limited Kitchener, ON Mr. Kenton Power Tel: 519 585-7108	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Stantec Consulting Limited Markham, ON Ms. Brani Vujanovic Tel: 905 479-9345	✓	✓		✓		✓	✓	✓			✓	✓	✓		✓	✓	✓	✓	✓
Steed and Evans Limited St. Jacobs, ON Mr. Richard Marco Tel: 519 699-4646	✓	✓		✓		✓	✓								✓				
Taranis Contracting Group Thunder Bay, ON Ms. Cheryl Thompson Tel: 807 475-5443	✓	✓				✓	✓								✓				
TBT Engineering Limited Thunder Bay, ON Mr. Tim Fummerton Tel: 807 624-5162	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
Teranorth Construction & Engineering Ltd. Sudbury, ON Mr. Edward Carriere Tel: 705 523-1540	✓	✓				✓	✓								✓	✓			
Terraprobe Inc. Brampton, ON Mr. Chris Elvidge Tel: 905 796-2650	✓	✓		✓		✓	✓					✓	✓		✓	✓	✓	✓	✓
Terraprobe Inc. Barrie, ON Mr. Brian Jackson Tel: 705 739-8355	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓

2014 Participants List

Ministry of Transportation
Aggregate and Soil
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Stephen Senior (416) 235-3734

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Terraprobe Inc. Stoney Creek, ON Mr. Gerry Muckle Tel: 905 643-7560	✓	✓		✓		✓	✓								✓	✓	✓	✓	✓
Terraprobe Inc. Sudbury, ON Mr. Dennis Paquette Tel: 705 670-0460	✓	✓				✓	✓								✓	✓	✓	✓	✓
Terraspec Engineering Inc. Peterborough, ON Mr. Shane Galloway Tel: 705 743-7880	✓	✓				✓	✓								✓	✓	✓	✓	✓
Tetra Tech EBA Calgary, AB Mr. Edahlia McNeil Tel: 403 723-1547	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓
The Karson Group Carp, ON Mr. Cam MacDonald Tel: 613 831-0717	✓	✓		✓	✓	✓	✓				✓	✓	✓	✓	✓				
The Miller.Group -Materials Research Lab Gormley, ON Mr. Richard Du Tel: 905 726-9518	✓	✓		✓	✓	✓	✓	✓			✓	✓	✓		✓	✓		✓	
The Murray Group Moorefield, ON Mr. Jerry Dunham Tel: 519 323-4411	✓	✓				✓	✓								✓				
Thomas Cavanagh Construction Ltd. Ashton, ON Mr. Phil White Tel: 613 257-2918	✓	✓		✓	✓	✓	✓				✓	✓	✓		✓	✓		✓	
Thurber Engineering Limited Ottawa, ON Mr. Fred Griffiths Tel: 613 247-2121	✓	✓				✓	✓								✓	✓	✓	✓	✓
Thurber Engineering Limited Oakville, ON Mr. Weiss Mehdawi Tel: 905 829-8666	✓	✓				✓	✓								✓	✓	✓	✓	✓
Tri City Materials Petersburg, ON Mr. Ron Shantz Tel: 519 577-1000	✓	✓				✓	✓								✓				
True Grit Consulting Ltd. Thunder Bay, ON Mr. Adam Rose Tel: 807 626-5640	✓	✓				✓	✓								✓	✓	✓	✓	✓
Tulloch Engineering Inc. Sault Ste. Marie, ON Mr. Joseph Febbraro Tel: 705 949-1457	✓	✓		✓		✓	✓					✓	✓		✓	✓	✓	✓	✓
Vicdom Sand and Gravel Limited Uxbridge, ON Mr. Bruno Giordano Tel: 905 649-2193	✓	✓				✓	✓								✓				
Walker Aggregates Inc. Thorold, ON Mr. Tom Risi Tel: 905 227-4142	✓	✓		✓	✓	✓	✓					✓	✓		✓				
Walker Aggregates Inc. Duntroon, ON Mr. Tom Risi Tel: 905 445-2300	✓	✓				✓	✓								✓				
Waynco Ltd. Cambridge, ON Mr. Mike Rook Tel: 519 623-0240	✓	✓				✓	✓								✓				

2014 Participants List

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WSP Canada Inc. Peterborough, ON Ms. Kelly Whitney Tel: 705 743-6850	✓	✓				✓	✓								✓	✓	✓	✓	✓

Appendix B2: List of Participants

2014 Participants List Ministry of Transportation Superpave Aggregate Consensus Property Testing Program For further information on this program, contact: Mark Vasavithasan (416) 235-4901 or Stephen Senior (416) 235-3734	LS-629 - Uncompacted Void Content of Fine Aggregate (AASHTO T 304)	ASTM D 2419/AASHTO T 176 – Sand Equivalent Value of Fine Aggregate	ASTM D 5821 – Percent of Fractured Particles in Coarse Aggregate	ASTM D 4791 – Percent Flat Particles, Elongated Particles or Flat & Elongated Particles in Coarse Aggregate
AGS Associates Inc. Scarborough, ON Mr. Amjed Siddiqui Tel: 416 299-3655	✓	✓	✓	✓
AME -Materials Engineering Caledon, ON Mr. Scott Crowley Tel: 905 840-5914	✓	✓	✓	✓
AME -Materials Engineering Ottawa, ON Mr. Harrison Smith Tel: 613 726-3039	✓	✓	✓	✓
AMEC Earth & Environmental Limited Cambridge, ON Ms. Tammy Hawkins Tel: 519 650-7116	✓	✓	✓	✓
AMEC Earth & Environmental Limited Hamilton, ON Mr. Ognienko Lazic Tel: 905 312-0700	✓	✓	✓	✓
AMEC Earth & Environmental Limited Scarborough, ON Mr. S. Baskaran Tel: 416 751-6565	✓	✓	✓	✓
AMEC Earth & Environmental Limited Tecumseh, ON Mr. Justin Palmer Tel: 519 735-2499	✓	✓	✓	✓
C. Villeneuve Construction – Mobile 1 Hearst, ON Mr. Charles Harris Tel: 705 372-1838	✓	✓	✓	✓
Cambium Inc. Peterborough, ON Mr. Wayne Rayfuse Tel: 705 741-4109	✓	✓	✓	✓
COCO Paving Inc. Belleville, ON Mr. Michael Haisma Tel: 613 962-3461	✓	✓	✓	✓
COCO Paving Inc. Windsor, ON Mr. Ishaq Syed Tel: 519 999-1840	✓	✓	✓	✓
COCO Paving Inc. Toronto, ON Mr. Oussama Ibrahim Tel: 416 346-5244	✓	✓	✓	✓
Construction Testing Asphalt Lab Cambridge, ON Mr. Peter Lung Tel: 519 622-7023	✓	✓	✓	✓
Cornwall Gravel Company Ltd. Cornwall, ON Ms. Billie-Gail Macfarlane Tel: 613 930-3530	✓	✓	✓	✓
Cox Construction Limited Guelph, ON Ms. Alana Smith Tel: 519 240-9071	✓		✓	✓
Cruickshank Construction Kingston, ON Mr. Tim Bilton Tel: 613 536-9112	✓	✓	✓	✓
Davroc Testing Laboratories Inc. Brampton, ON Mr. Sal Fasullo Tel: 905 792-7792	✓	✓	✓	✓
DBA Engineering Limited Kingston, ON Mr. Mark McClelland Tel: 613 389-1781	✓	✓	✓	✓
DBA Engineering Limited Vaughan, ON Mr. Zlatko Brcic Tel: 905 851-0090	✓	✓	✓	✓

2014 Participants List

Ministry of Transportation

Superpave Aggregate Consensus Property Testing Program

For further information on this *program, contact:*

Mark Vasavithasan (416) 235-4901 or

Stephen Senior (416) 235-3734

	LS-629 - Uncompacted Void Content of Fine Aggregate (AASHTO T 304)	ASTM D 2419/AASHTO T 176 – Sand Equivalent Value of Fine Aggregate	ASTM D 5821 – Percent of Fractured Particles in Coarse Aggregate	ASTM D 4791 – Percent Flat Particles, Elongated Particles or Flat & Elongated Particles in Coarse Aggregate
DST Consulting Engineers Inc. Thunder Bay, ON Dr. Myint Win Bo Tel: 807 623-2929	✓	✓	✓	✓
Dufferin Construction Ltd. (QC) - Bronte Oakville, ON Mr. Ronald Abdul Tel: 416 891-0597	✓	✓	✓	✓
Duncor Enterprises Inc. Barrie, ON Mr. Peter Smith Tel: 705 730-1999		✓		
Engtec Consulting Inc. Vaughan, ON Mr. Salman Bhutta Tel: 905 856-2988	✓	✓	✓	✓
exp Services Inc. Brampton, ON Mr. Ammanuel Yousif Tel: 905 793-9800	✓	✓	✓	✓
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2014 Participants List

Ministry of Transportation
Superpave Aggregate Consensus Property Testing Program

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			LS-629 - Uncompacted Void Content of Fine Aggregate (AASHTO T 304)	ASTM D 2419/AASHTO T 176 – Sand Equivalent Value of Fine Aggregate	ASTM D 5821 – Percent of Fractured Particles in Coarse Aggregate	ASTM D 4791 – Percent Flat Particles, Elongated Particles or Flat & Elongated Particles in Coarse Aggregate
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Appendix C: Multi-Laboratory Precision

Test 1	2011		2012		2013		2014		MTO LS-601
WP 75 µm	1.11	1.11	1.12	1.12	1.13	2.13	1.14	2.14	
Mean	0.97	1.11	2.39	2.26	1.22	1.22	1.00	1.15	< 2.5
1S	0.25	0.29	0.31	0.32	0.28	0.25	0.16	0.18	0.20
D2S	0.71	0.83	0.86	0.90	0.79	0.72	0.45	0.51	0.58
n/Outliers	210/11		199/18		201/21		205/21		

Test 2	2011		2012		2013		2014		ASTM C136[A]
P 19.0 mm	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	96.5	96.2	95.0	93.7	95.8	95.8	96.7	96.9	100 - 95
1S	0.7	0.8	1.0	1.1	0.8	0.8	0.7	0.6	0.35
D2S	1.9	2.1	2.8	3.1	2.4	2.4	1.9	1.7	1.0
n/Outliers	215/7		215/2		213/10		220/6		

Test 3	2011		2012		2013		2014		ASTM C136[A]
P 16.0 mm	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	86.4	85.3	90.2	87.6	90.0	89.9	88.6	89.2	95 - 85
1S	1.1	1.6	1.6	1.6	1.1	1.2	1.1	1.0	1.37
D2S	3.0	4.6	4.6	4.6	3.1	3.5	3.0	2.9	3.9
n/Outliers	208/14		211/5		207/15		221/5		

Test 4	2011		2012		2013		2014		ASTM C136[A]
P 13.2 mm	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	76.2	74.4	85.4	82.0	83.7	83.6	79.5	80.6	85 - 80
1S	1.4	2.1	1.9	1.8	1.5	1.5	1.3	1.4	1.92
D2S	3.8	5.9	5.5	5.2	4.3	4.3	3.7	4.1	5.4
n/Outliers	214/8		209/8		209/14		219/7		

Test 5	2011		2012		2013		2014		ASTM C136[A]
P 9.5 mm	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	62.0	59.6	75.8	71.5	72.1	71.8	63.4	65.1	80 – 60
1S	1.7	2.3	2.3	2.2	1.6	1.7	1.3	1.7	2.82
D2S	4.8	6.4	6.4	6.4	4.5	4.8	3.8	4.7	8.0
n/Outliers	215/7		210/7		201/22		214/12		

Test 6	2011		2012		2013		2014		ASTM C136[A]
P 4.75 mm	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	46.5	44.0	58.1	53.8	54.8	54.2	45.3	46.9	60 – 20
1S	1.8	2.0	2.3	2.2	1.5	1.7	1.3	1.5	1.97
D2S	5.1	5.7	6.6	6.2	4.3	4.9	3.6	4.3	5.6
n/Outliers	211/11		207/10		204/19		214/12		

Test 8	2011		2012		2013		2014		ASTM C131	
L. A	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	C of V	σ^*
Mean	24.2	23.8	22.6	21.9	22.2	22.1	26.4	26.5	10-45	26.5
1S	1.02	1.40	1.32	1.34	1.2	0.9	1.3	1.1	4.5%	1.2
D2S	2.89	3.96	3.73	3.81	3.3	2.5	3.7	3.2	12.7%	3.4
n/Outliers	12/1		11/0		9/1		11/0			

A – AMRL reports percent passing inch series equivalent sieves.

σ^* - Calculated from Coefficient of Variation Precision Statement (Coefficient of Variation = Standard Deviation / Mean)

Test 9 RD (O.D.)	2011		2012		2013		2014		MTO LS-604
	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	2.670	2.669	2.655	2.657	2.625	2.624	2.666	2.665	
1S	0.007	0.007	0.008	0.008	0.006	0.006	0.007	0.006	0.006
D2S	0.020	0.020	0.023	0.023	0.017	0.017	0.020	0.017	0.016
n/Outliers	96/11		102/3		98/6		93/6		

Test 10 ABS	2011		2012		2013		2014		MTO LS-604
	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	0.709	0.703	2.094	2.063	1.133	1.126	0.734	0.740	< 2%
1S	0.087	0.088	0.121	0.134	0.076	0.072	0.078	0.079	0.09
D2S	0.246	0.249	0.342	0.379	0.215	0.204	0.220	0.223	0.25
n/Outliers	101/6		102/3		101/3		94/5		

Test 11 $MgSO_4$	2011		2012		2013		2014		ASTM C88	
	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	C of V	σ^*
Mean	15.1	14.9	26.1	25.3	3.7	3.5	4.8	4.7	9-20%	4.8
1S	2.9	2.2	5.4	5.3	1.8	1.9	1.4	1.0	25%	1.2
D2S	8.3	6.2	15.2	15.0	5.0	5.3	4.1	2.8	71%	3.4
n/Outliers	40/4		42/1		44/0		39/4			

Test 12 % Crush	2011		2012		2013		2014		MTO LS-607
	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	63.1	63.7	76.9	77.5	69.1	69.3	76.4	76.4	55% - 85%
1S	4.2	4.1	5.6	5.9	3.8	3.7	3.2	3.3	4.7
D2S	12.0	11.5	15.8	16.7	10.8	10.6	9.1	9.5	13.2
n/Outliers	202/20		201/15		208/14		208/18		

Test 13 % F & E	2011		2012		2013		2014		MTO LS-608
	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	2.4	2.5	3.7	3.6	6.9	6.7	4.9	4.5	2.0% - 9.5%
1S	1.2	1.3	1.8	1.9	2.5	2.4	1.8	1.7	2.3
D2S	3.3	3.5	5.1	5.3	7.2	6.7	5.1	5.0	6.4
n/Outliers	201/18		203/11		215/6		216/10		

Test 14 PN Conc.	2011		2012		2013		2014		MTO LS-609
	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	-	-	131.4	127.7	-	-	112.8	112.0	No Precision
1S	-	-	15.4	10.0	-	-	5.3	5.4	Statements for
D2S	-	-	43.3	24.7	-	-	14.9	15.4	this Test.
n/Outliers	28		28/8		35		28/5		

Test 16 MDA, CA	2011		2012		2013		2014		MTO LS-618	
	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	C of V	σ
Mean	22.8	22.7	19.2	19.1	11.5	11.5	11.8	11.9	5-23%	11.9
1S	0.95	1.03	1.14	0.92	0.45	0.54	0.64	0.69	5.4%	0.64
D2S	2.70	2.91	3.23	2.59	1.27	1.52	1.82	1.95	15.2%	1.82
n/Outliers	70/7		72/5		76/4		75/3			

Test 17 Freeze-thaw	2011		2012		2013		2014		MTO LS-614	
	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	C of V	σ
Mean	10.40	10.31	10.11	9.77	3.30	3.16	8.71	8.64	3-18%	8.68
1S	2.15	2.20	2.82	3.00	1.10	1.13	2.08	1.87	21.6%	1.87
D2S	6.09	6.21	8.00	8.51	3.10	3.19	5.89	5.29	61.0%	5.30
n/Outliers	55/2		58/1		60/2		58/3			

A – AMRL reports percent passing inch series equivalent sieves.

σ^* - Calculated from Coefficient of Variation Precision Statement (Coefficient of Variation = Standard Deviation / Mean)

Test 20	2011		2012		2013		2014		ASTM C136[A]
P 2.36 mm	3.11	4.11	3.12	4.12	3.13	4.13	3.14	4.14	
Mean	37.4	35.6	43.2	40.3	44.9	44.5	35.3	36.6	60 - 20
1S	1.9	1.9	2.5	2.3	1.9	1.8	1.5	1.8	1.41
D2S	5.4	5.4	7.0	6.4	5.5	5.0	4.2	5.1	4.0
n/Outliers	219/3		203/14		207/16		212/14		

Test 21	2011		2012		2013		2014		ASTM C136[A]
P 1.18 mm	3.11	4.11	3.12	4.12	3.13	4.13	3.14	4.14	
Mean	30.1	28.7	30.2	28.5	37.6	37.3	26.6	27.7	60 - 20
1S	1.9	1.8	2.2	2.1	1.9	1.7	1.6	1.8	1.41
D2S	5.3	5.1	6.2	5.9	5.5	4.9	4.4	5.1	4.0
n/Outliers	219/3		205/12		209/14		214/12		

Test 22	2011		2012		2013		2014		ASTM C136[A]
P 600 µm	3.11	4.11	3.12	4.12	3.13	4.13	3.14	4.14	
Mean	22.0	21.0	22.0	21.0	27.4	27.4	17.9	18.6	20 - 15
1S	1.5	1.4	1.6	1.7	1.5	1.5	1.2	1.4	1.10
D2S	4.3	3.9	4.5	4.9	4.3	4.3	3.5	4.1	3.1
n/Outliers	216/6		201/16		203/20		214/12		

Test 23	2011		2012		2013		2014		ASTM C136[A]
P 300 µm	3.11	4.11	3.12	4.12	3.13	4.13	3.14	4.14	
Mean	12.6	12.2	16.5	16.0	14.1	14.1	10.2	10.5	15 - 10
1S	0.8	0.8	1.2	1.2	0.84	0.85	0.8	0.9	0.73
D2S	2.3	2.3	3.5	3.4	2.4	2.4	2.2	2.6	2.1
n/Outliers	214/8		199/18		203/20		214/12		

Test 24	2011		2012		2013		2014		ASTM C136[A]
P 150 µm	3.11	4.11	3.12	4.12	3.13	4.13	3.14	4.14	
Mean	8.1	7.8	12.3	12.0	10.3	10.3	6.2	6.3	10 - 2
1S	0.5	0.5	0.8	0.8	0.6	0.6	0.5	0.5	0.65
D2S	1.4	1.4	2.3	2.3	1.8	1.8	1.4	1.3	1.8
n/Outliers	206/16		198/19		210/13		206/20		

Test 25	2011		2012		2013		2014		ASTM C136[A]
P 75 µm	3.11	4.11	3.12	4.12	3.13	4.13	3.14	4.14	
Mean	6.0	5.8	9.1	8.8	8.7	8.7	4.4	4.4	10 - 2
1S	0.4	0.4	0.6	0.6	0.5	0.5	0.3	0.4	0.65
D2S	1.0	1.0	1.7	1.7	1.5	1.5	1.0	1.1	1.8
n/Outliers	206/16		200/17		214/9		213/12		

Test 27	2011		2012		2013		2014		MTO LS-605
RD (O.D.)	3.11	4.11	3.12	4.12	3.13	4.13	3.14	4.14	
Mean	2.654	2.654	2.647	2.649	2.650	2.650	2.666	2.665	
1S	0.010	0.011	0.011	0.009	0.013	0.013	0.009	0.011	0.012
D2S	0.028	0.031	0.031	0.025	0.037	0.037	0.025	0.031	0.034
n/Outliers	99/5		95/10		99/4		90/8		

Test 28	2011		2012		2013		2014		MTO LS-605
ABS	3.11	4.11	3.12	4.12	3.13	4.13	3.14	4.14	
Mean	0.700	0.684	1.171	1.148	1.351	1.329	0.709	0.719	< 2.0%
1S	0.12	0.12	0.15	0.16	0.16	0.12	0.12	0.13	0.16
D2S	0.34	0.34	0.44	0.46	0.44	0.34	0.34	0.36	0.44
n/Outliers	94/10		96/9		93/10		92/6		

A – AMRL reports percent passing inch series equivalent sieves.

σ^* - Calculated from Coefficient of Variation Precision Statement (Coefficient of Variation = Standard Deviation / Mean)

Test 30	2011		2012		2013		2014		MTO LS-621
% ACP	1.11	1.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	36.4	37.0	47.1	47.6	54.4	54.8	45.7	39.4	25% - 55%
1S	3.5	3.3	5.4	5.2	2.9	3.0	5.0	4.9	3.9
D2S	9.8	9.2	15.2	14.8	8.1	8.4	14.3	13.7	11.1
n/Outliers	214/7		205/11		202/20		211/14		

Test 31	2011		2012		2013		2014		MTO LS-623
MWD	3.11	4.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	2.315	2.318	2.416	2.421	2.422	2.425	2.365	2.367	
1S	0.033	0.038	0.032	0.032	0.024	0.024	0.029	0.027	0.030
D2S	0.093	0.107	0.090	0.090	0.070	0.070	0.082	0.076	0.084
n/Outliers	150/10		133/14		141/14		144/12		

Test 32	2011		2012		2013		2014		MTO LS-623
MDD	3.11	4.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	2.147	2.154	2.257	2.264	2.265	2.267	2.200	2.204	
1S	0.032	0.033	0.035	0.034	0.025	0.027	0.030	0.026	0.032
D2S	0.090	0.093	0.099	0.096	0.071	0.076	0.085	0.073	0.091
n/Outliers	146/14		140/7		144/11		147/9		

Test 33	2011		2012		2013		2014		MTO LS-623
OMC	3.11	4.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	7.99	7.94	7.13	7.07	7.05	7.02	7.57	7.55	
1S	0.30	0.28	0.33	0.33	0.26	0.26	0.23	0.26	0.36
D2S	0.85	0.79	0.93	0.92	0.74	0.74	0.66	0.72	1.02
n/Outliers	141/19		144/3		146/9		145/11		

Test 34	2011		2012		2013		2014		MTO LS-619	
MDA, FA3	3.11	4.11	3.12	4.12	3.13	4.13	3.14	4.14	C of V	σ
Mean	10.7	10.7	17.6	17.7	15.6	15.7	10.3	10.4	7-18%	10.4
1S	0.8	0.9	1.1	1.1	1.2	1.2	0.8	0.9	7.6%	0.8
D2S	2.1	2.6	3.0	3.0	3.4	3.4	2.2	2.5	21.4%	2.2
n/Outliers	74/3		71/6		79/1		73/5			

Test 40	2011		2012		2013		2014		MTO LS-702
P 2.0 mm	5.11	6.11	5.12	6.12	5.13	6.13	5.14	6.14	
Mean	99.0	98.9	100	100	99.6	99.8	99.9	99.8	No MTO
1S	0.6	0.7			0.3	0.2	0.1	0.1	precision
D2S	1.7	1.8			0.9	0.5	0.3	0.3	statements for
n/Outliers	71/5		76/0		90/0		88/0		this test

Test 41	2011		2012		2013		2014		MTO LS-702
P 425 µm	5.11	6.11	5.12	6.12	5.13	6.13	5.14	6.14	
Mean	96.2	95.9	99.8	99.8	96.7	97.0	97.6	97.6	No MTO
1S	0.7	0.9	0.2	0.2	0.7	0.5	0.3	0.3	precision
D2S	2.1	2.7	0.5	0.5	1.9	1.5	1.0	1.00	statements for
n/Outliers	67/9		71/5		86/4		80/8		this test

Test 42	2011		2012		2013		2014		MTO LS-702
P 75 µm	5.11	6.11	5.12	6.12	5.13	6.13	5.14	6.14	
Mean	90.7	90.4	99.1	99.1	91.3	91.7	93.0	93.1	No MTO
1S	1.1	1.2	0.3	0.3	1.0	0.9	0.4	0.4	precision
D2S	3.1	3.5	1.0	1.0	2.9	2.6	1.2	1.2	statements for
n/Outliers	69/7		71/5		88/2		79/9		this test

A – AMRL reports percent passing inch series equivalent sieves.

σ^{*} - Calculated from Coefficient of Variation Precision Statement (Coefficient of Variation = Standard Deviation / Mean)

Test 43	2011		2012		2013		2014		MTO LS-702
P 20 µm	5.11	6.11	5.12	6.12	5.13	6.13	5.14	6.14	
Mean	78.0	77.6	80.6	80.6	79.3	79.3	85.4	85.9	No MTO precision statements for this test
1S	4.2	4.0	4.2	4.2	3.4	3.1	2.7	2.7	
D2S	12.0	11.4	12.0	12.0	9.5	8.7	7.6	7.6	
n/Outliers	74/2		74/2		85/5		80/8		

Test 44	2011		2012		2013		2014		MTO LS-702
P 5 µm	5.11	6.11	5.12	6.12	5.13	6.13	5.14	6.14	
Mean	58.2	58.3	43.7	43.9	59.4	58.9	76.1	76.9	No MTO precision statements for this test
1S	4.3	3.9	2.7	2.6	3.4	3.1	3.0	3.0	
D2S	12.1	11.0	7.7	7.2	9.6	8.7	8.6	8.6	
n/Outliers	73/3		71/5		84/6		78/10		

Test 45	2011		2012		2013		2014		MTO LS-702
P 2 µm	5.11	6.11	5.12	6.12	5.13	6.13	5.14	6.14	
Mean	43.6	43.7	28.6	28.8	43.9	43.9	65.5	66.1	No MTO precision statements for this test
1S	3.0	3.2	2.3	2.3	2.4	2.8	3.2	3.2	
D2S	8.5	9.1	6.6	6.6	6.8	8.0	8.9	8.9	
n/Outliers	72/4		72/4		81/9		78/10		

Test 46	2011		2012		2013		2014		ASTM D4318
L. L	5.11	6.11	5.12	6.12	5.13	6.13	5.14	6.14	
Mean	36.6	36.7	32.2	32.2	37.1	37.1	48.1	48.3	59.9
1S	1.3	1.6	1.2	1.2	1.3	1.4	1.9	2.2	2.1
D2S	3.7	4.4	3.3	3.3	3.8	3.9	5.5	6.3	6
n/Outliers	88/6		89/6		103/5		99/9		

Test 47	2011		2012		2013		2014		ASTM D4318
P. L	5.11	6.11	5.12	6.12	5.13	6.13	5.14	6.14	
Mean	18.6	18.7	18.9	18.9	18.8	18.7	21.2	21.2	20.4
1S	1.4	1.3	1.1	1.1	1.3	1.1	1.6	1.6	2.7
D2S	3.9	3.7	3.1	3.1	3.6	3.2	4.7	4.7	7
n/Outliers	92/2		86/9		104/4		101/7		

Test 48	2011		2012		2013		2014		ASTM D4318
P. I	5.11	6.11	5.12	6.12	5.13	6.13	5.14	6.14	
Mean	17.9	17.9	13.3	13.4	18.4	18.3	26.8	27.0	39.5
1S	1.6	1.6	1.7	1.7	1.6	1.4	1.9	2.3	3.1
D2S	4.6	4.6	4.8	4.8	4.5	4.1	5.5	6.5	9
n/Outliers	89/5		93/2		101/7		102/6		

Test 49	2011		2012		2013		2014		AASHTO T 100
SG of Soils	5.11	6.11	5.12	6.12	5.13	6.13	5.14	6.14	
Mean	2.734	2.734	2.721	2.718	2.733	2.734	2.755	2.758	
1S	0.032	0.034	0.023	0.023	0.024	0.025	0.030	0.031	0.04
D2S	0.090	0.096	0.065	0.065	0.068	0.071	0.085	0.088	0.11
n/Outliers	63/5		60/10		74/9		82/7		

A – AMRL reports percent passing inch series equivalent sieves.

$\hat{\sigma}$ - Calculated from Coefficient of Variation Precision Statement (Coefficient of Variation = Standard Deviation / Mean)

Test 95	2011		2012		2013		2014		ASTM C1252
UC Void	3.11	4.11	3.12	4.12	3.13	4.13	3.14	4.14	
Mean	40.87	40.87	44.0	44.1	42.2	42.3	42.8	42.8	ASTM C1252[A]
1S	0.71	0.54	0.66	0.63	0.64	0.65	0.60	0.48	0.33%
D2S	2.00	1.53	1.86	1.78	1.80	1.85	1.71	1.37	0.93%
n/Outliers	59/7		66/5		71/1		62/2		

Test 96	2011		2012		2013		2014		ASTM D2419
SE Value	3.11	4.11	3.12	4.12	3.13	4.13	3.14	4.14	
Mean	36.8	35.8	32.5	32.0	42.8	42.7	66.3	66.1	< 80
1S	3.81	4.29	3.62	3.67	8.0	7.7	4.9	4.9	8.0
D2S	10.79	12.15	10.24	10.38	22.7	21.8	14.0	14.0	22.6
n/Outliers	56/7		65/2		68/0		59/2		

Test 97	2011		2012		2013		2014		ASTM D5821
% Fractured	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	63.6	64.2	78.5	78.8	71.4	71.4	79.0	79.2	76.0%
1S	4.9	5.4	5.4	6.4	4.6	4.3	2.3	2.5	5.2%
D2S	13.8	15.3	15.4	18.1	12.9	12.2	6.4	7.0	14.7%
n/Outliers	69/2		70/2		72/2		64/4		

Test 99	2011		2012		2013		2014		ASTM D4791
% F & E	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	0.24	0.31	0.66	0.55	1.43	1.43	1.12	1.13	19.0 -12.5 mm
1S	0.19	0.26	0.46	0.32	0.80	0.78	0.61	0.65	88.5%
D2S	0.53	0.73	1.30	0.89	2.27	2.21	1.72	1.84	250.3%
n/Outliers	65/7		66/6		72/2		66/2		

Test 123	2011		2012		2013		2014		ASTM C1260
Mortar Bar	1.11	2.11	1.12	2.12	1.13	2.13	1.14	2.14	
Mean	Not Conducted		Not Conducted		Not Conducted		Not Conducted		Expansion >0.1%
1S									15.2%
D2S									43%
n/Outliers									

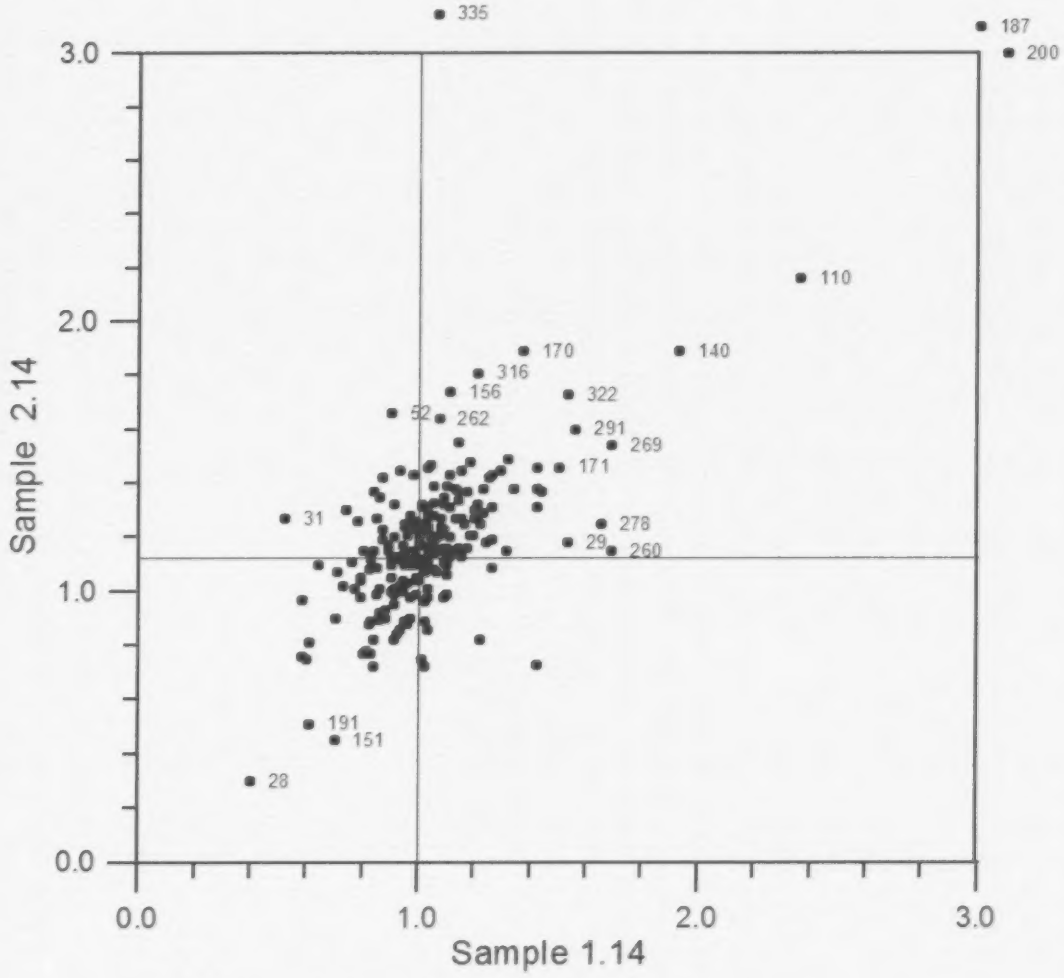
Test 15	2014		2015		2016		2017		ASTM D3042
% Residue	3.14	4.14	3.15	4.15	3.16	4.16	3.17	4.17	
Mean	40.2	41.1							48.2%
1S	8.8	6.7							2.7
D2S	24.9	19.1							7.7
n/Outliers	15/1								

Test 98	2014		2015		2016		2017		ASTM D3042
% Retained	3.14	4.14	3.15	4.15	3.16	4.16	3.17	4.17	
Mean	39.0	36.8							3.1
1S	2.4	4.0							8.9
D2S	6.7	11.2							
n/Outliers	11/5								

A – AMRL reports percent passing inch series equivalent sieves.

$\hat{\sigma}$ - Calculated from Coefficient of Variation Precision Statement (Coefficient of Variation = Standard Deviation / Mean)

Appendix D1: Scatter Diagrams



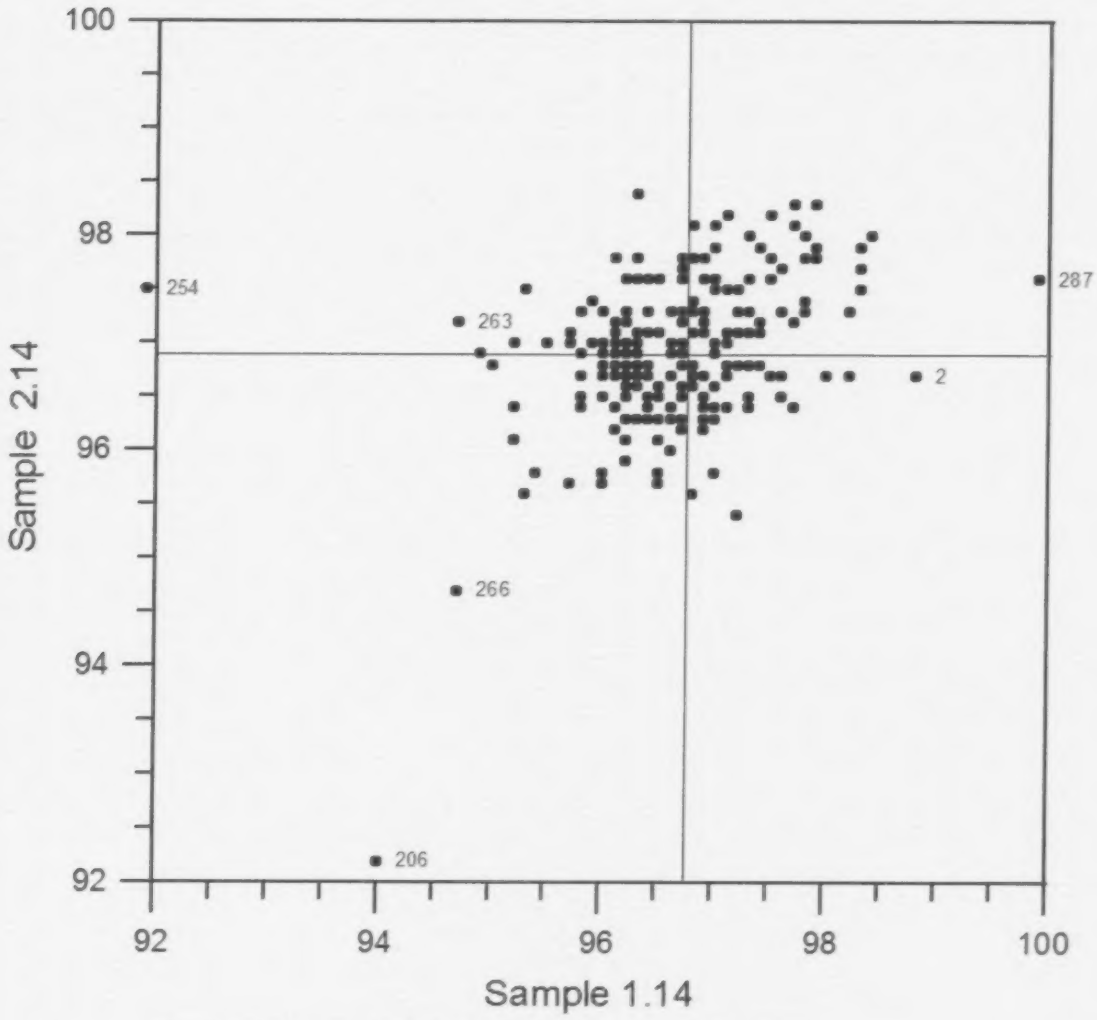
Test 1: Wash Pass 75 um

	Mat 1	Mat 2
Mean	1.002	1.147
Median	1.010	1.135
Std Dev	0.161	0.179

n = 205

Labs Eliminated: 28; 29; 31; 52; 110; 140; 151; 156; 170; 171; 187; 191; 200; 260; 262; 269; 278; 291; 316; 322; 335

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



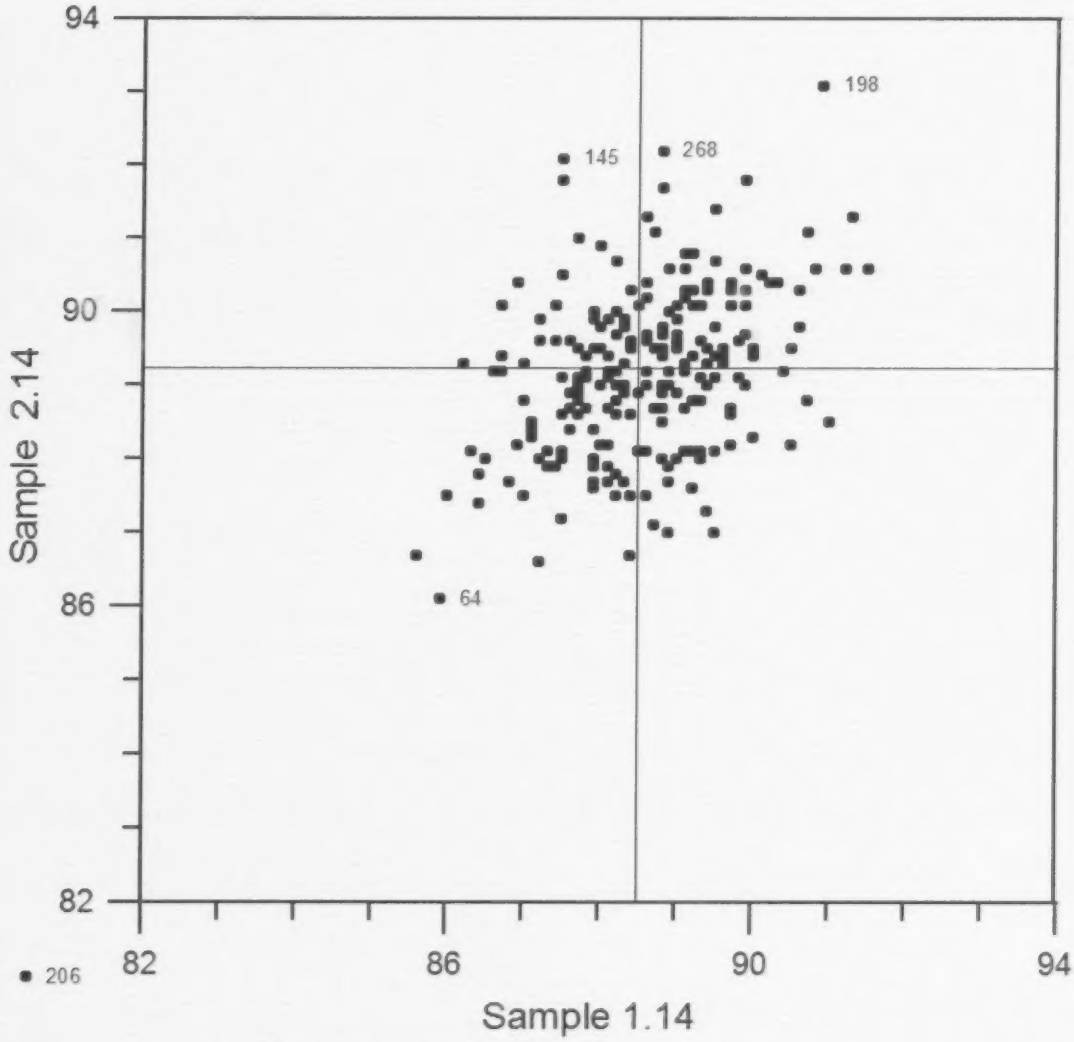
Test 2: Percent Passing the 19.0 mm Sieve

	Mat 1	Mat 2
Mean	96.705	96.945
Median	96.650	96.900
Std Dev	0.674	0.596

n = 220

Labs Eliminated: 2; 206; 254; 263; 266; 287

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



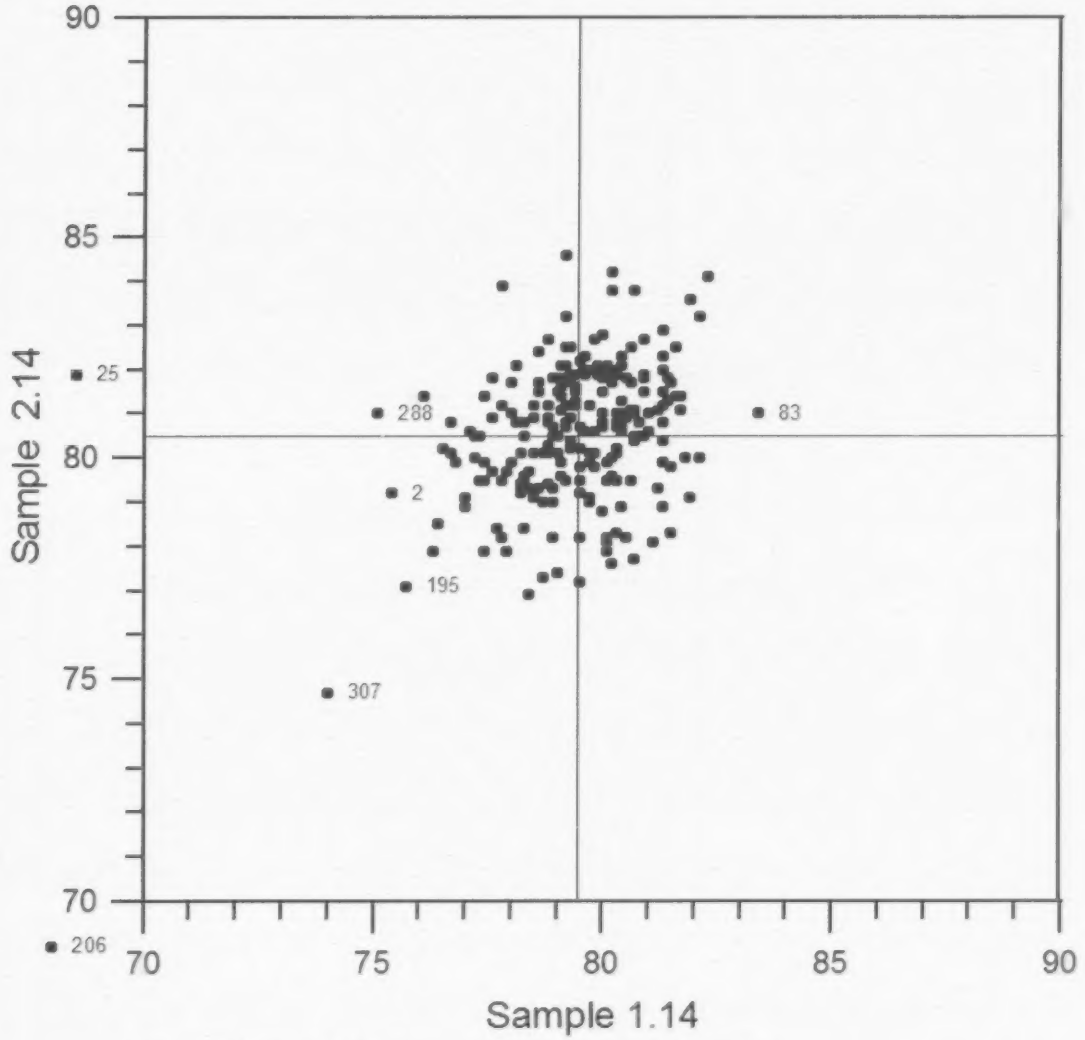
Test 3: Percent Passing the 16.0 mm Sieve

	Mat 1	Mat 2
Mean	88.566	89.178
Median	88.550	89.200
Std Dev	1.078	1.034

n = 221

Labs Eliminated: 64; 145; 198; 206; 268

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



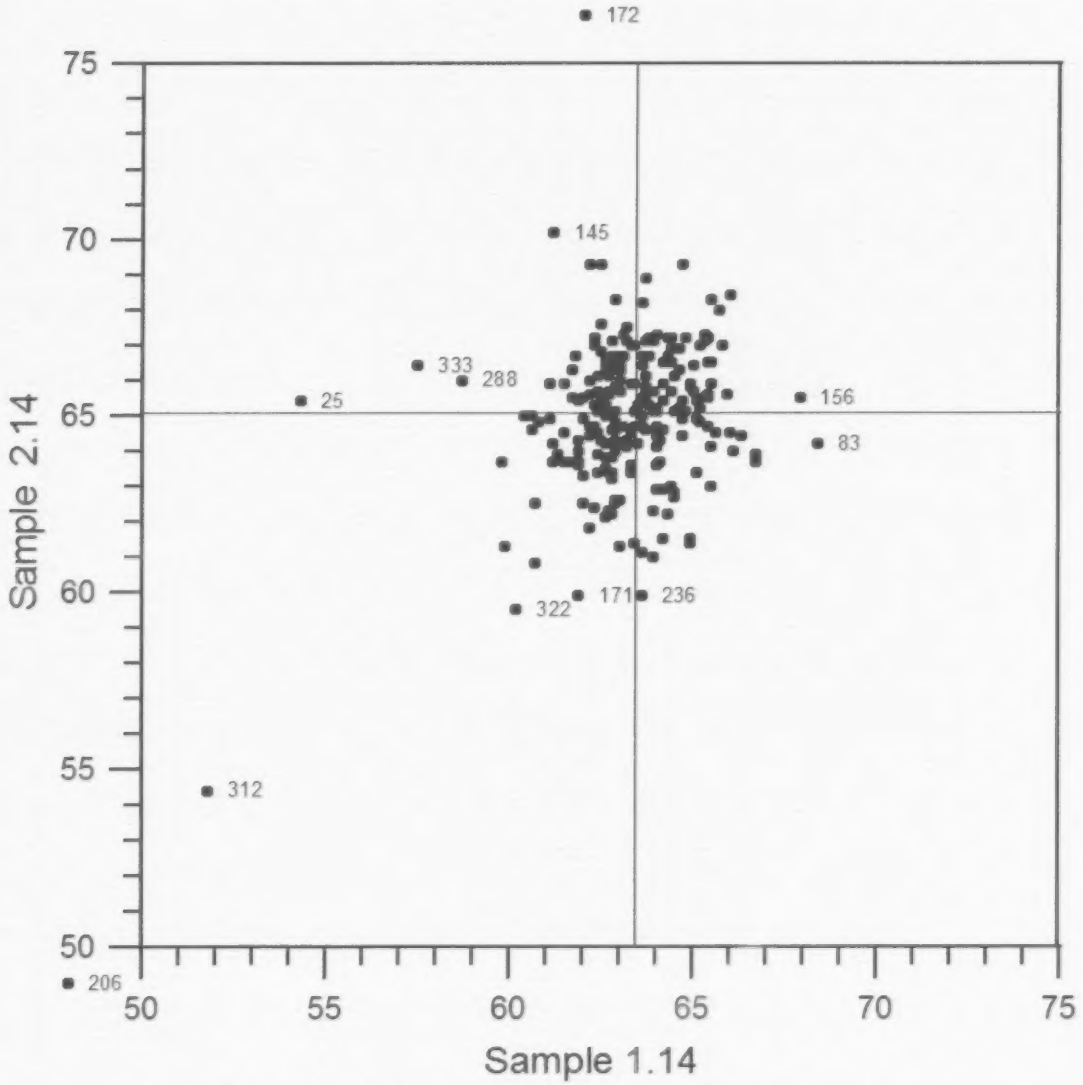
Test 4: Percent Passing the 13.20 mm Sieve

	Mat 1	Mat 2
Mean	79.496	80.610
Median	79.200	80.750
Std Dev	1.302	1.457

n = 219

Labs Eliminated: 2; 25; 83; 195; 206; 288; 307

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



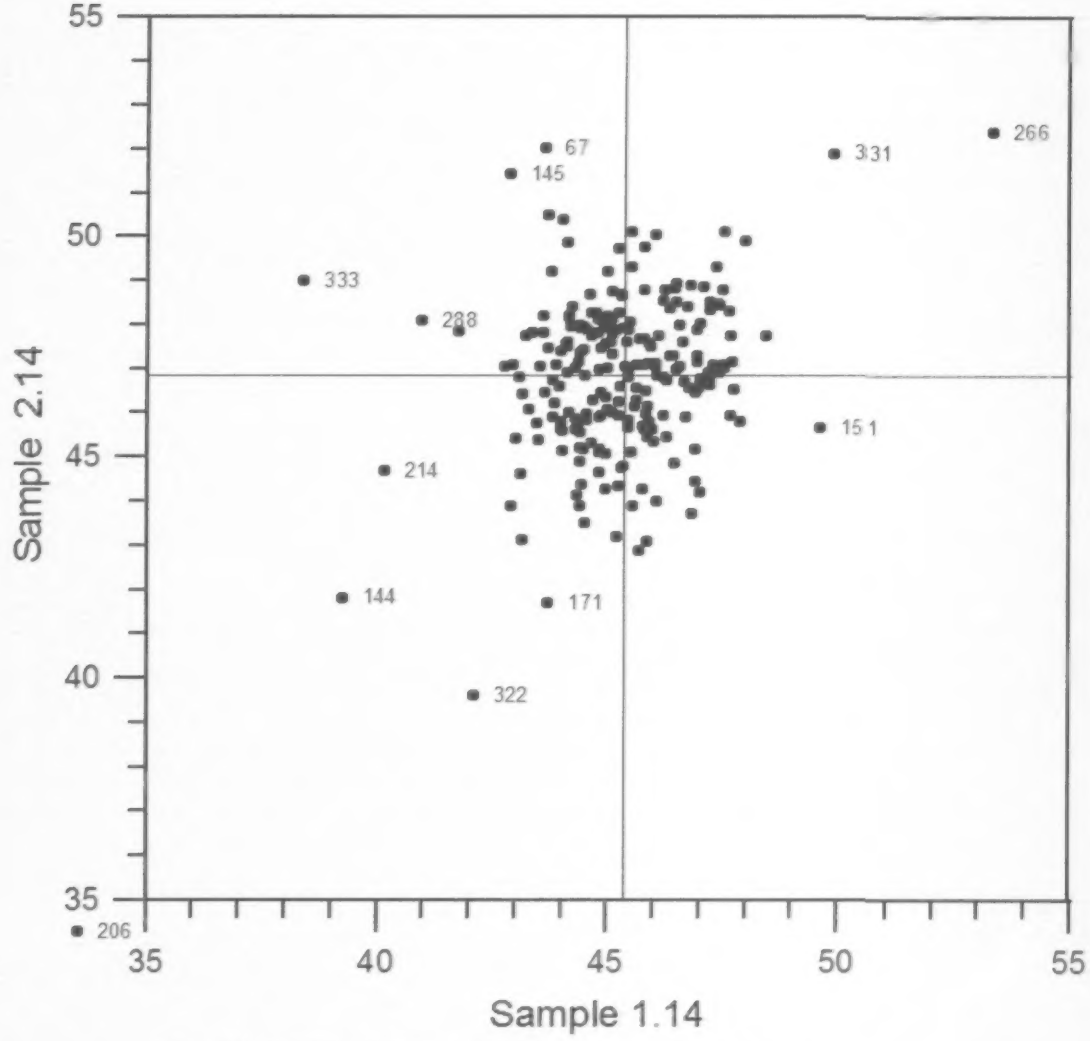
Test 5: Percent Passing the 9.5 mm Sieve

	Mat 1	Mat 2
Mean	63.395	65.088
Median	63.250	65.050
Std Dev	1.350	1.678

n = 214

Labs Eliminated: 25; 83; 145; 156; 171; 172; 206; 236; 288; 312; 322; 333

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



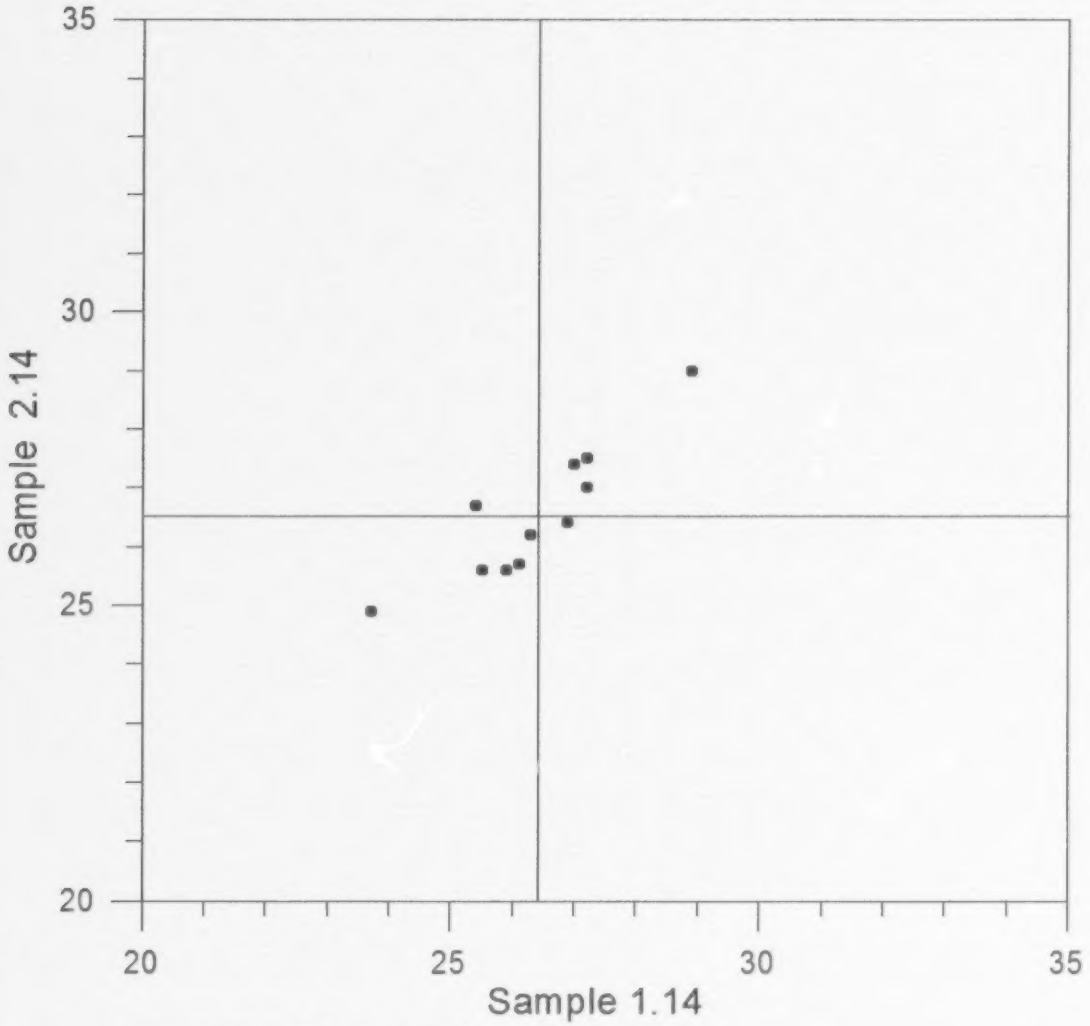
Test 6: Percent Passing the 4.75 mm Sieve

	Mat 1	Mat 2
Mean	45.301	46.912
Median	45.095	46.695
Std Dev	1.285	1.537

n = 214

Labs Eliminated: 67; 144; 145; 151; 171; 206; 214; 266; 288; 322; 331; 333

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



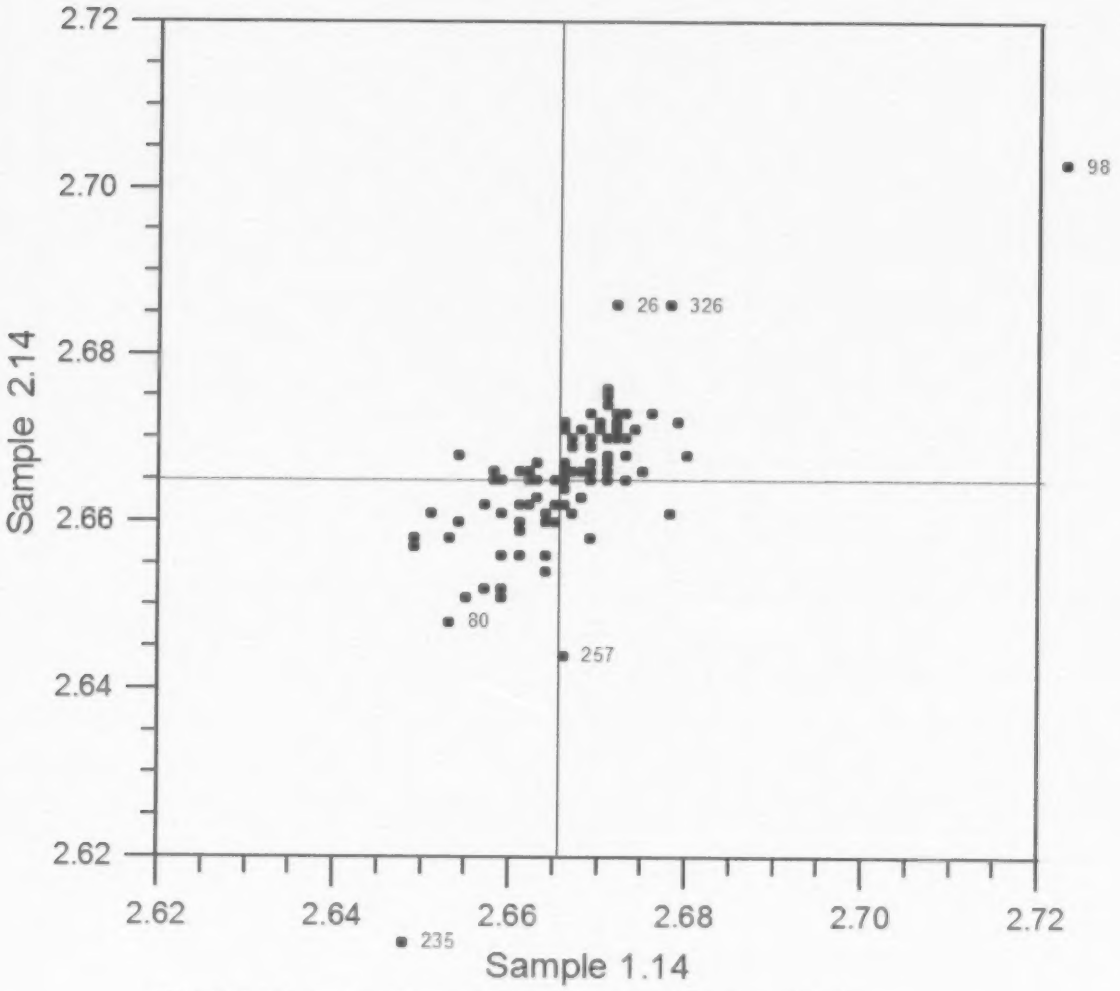
Test 8: Los Angeles Abrasion Loss, %

	Mat 1	Mat 2
Mean	26.373	26.545
Median	26.300	26.950
Std Dev	1.326	1.151

n = 11

Labs Eliminated: None

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



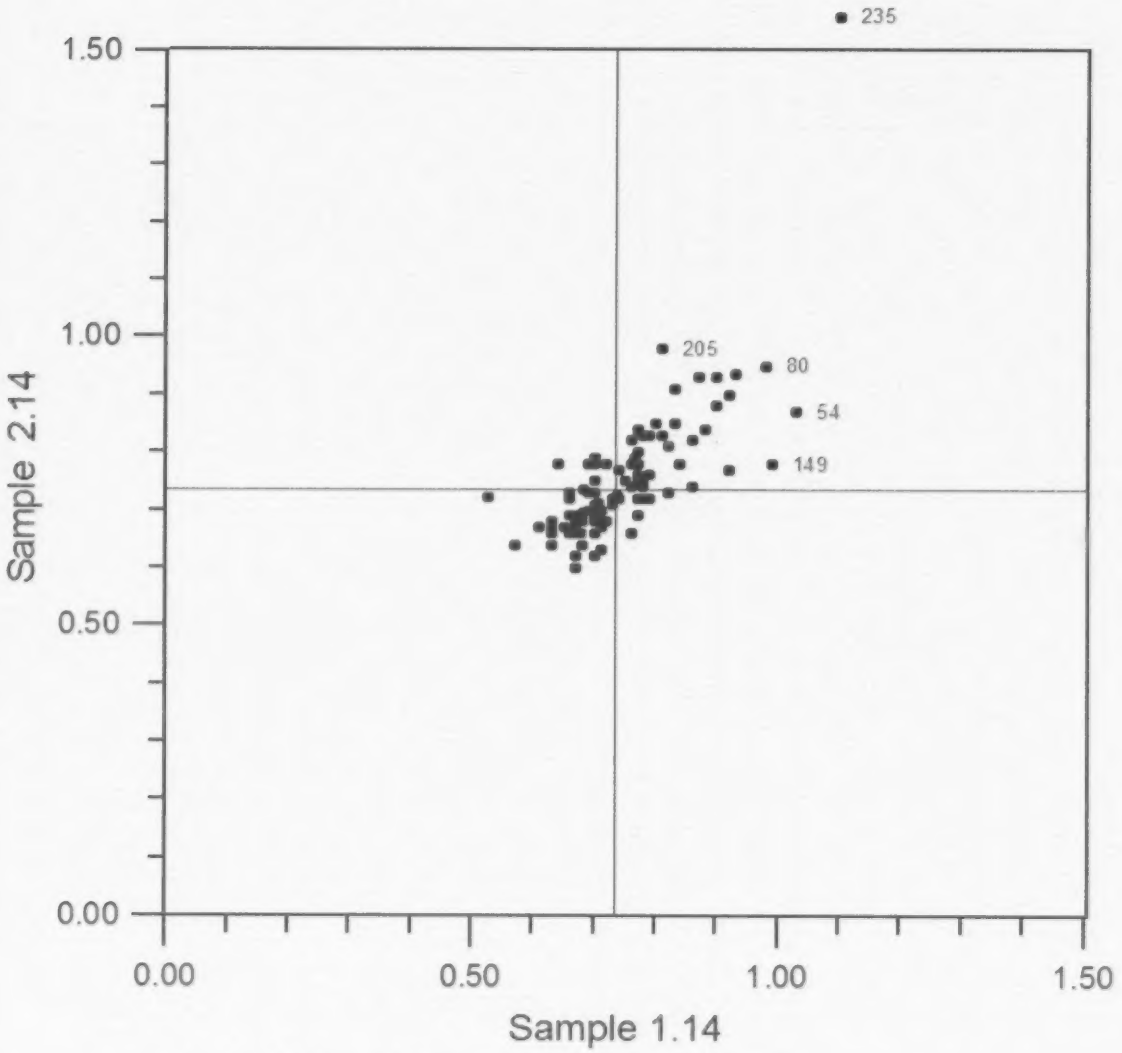
Test 9: Relative Density of Coarse Aggregate (O. D)

	Mat 1	Mat 2
Mean	2.666	2.665
Median	2.664	2.664
Std Dev	0.007	0.006

n = 93

Labs Eliminated: 26; 80; 98; 235; 257; 326

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



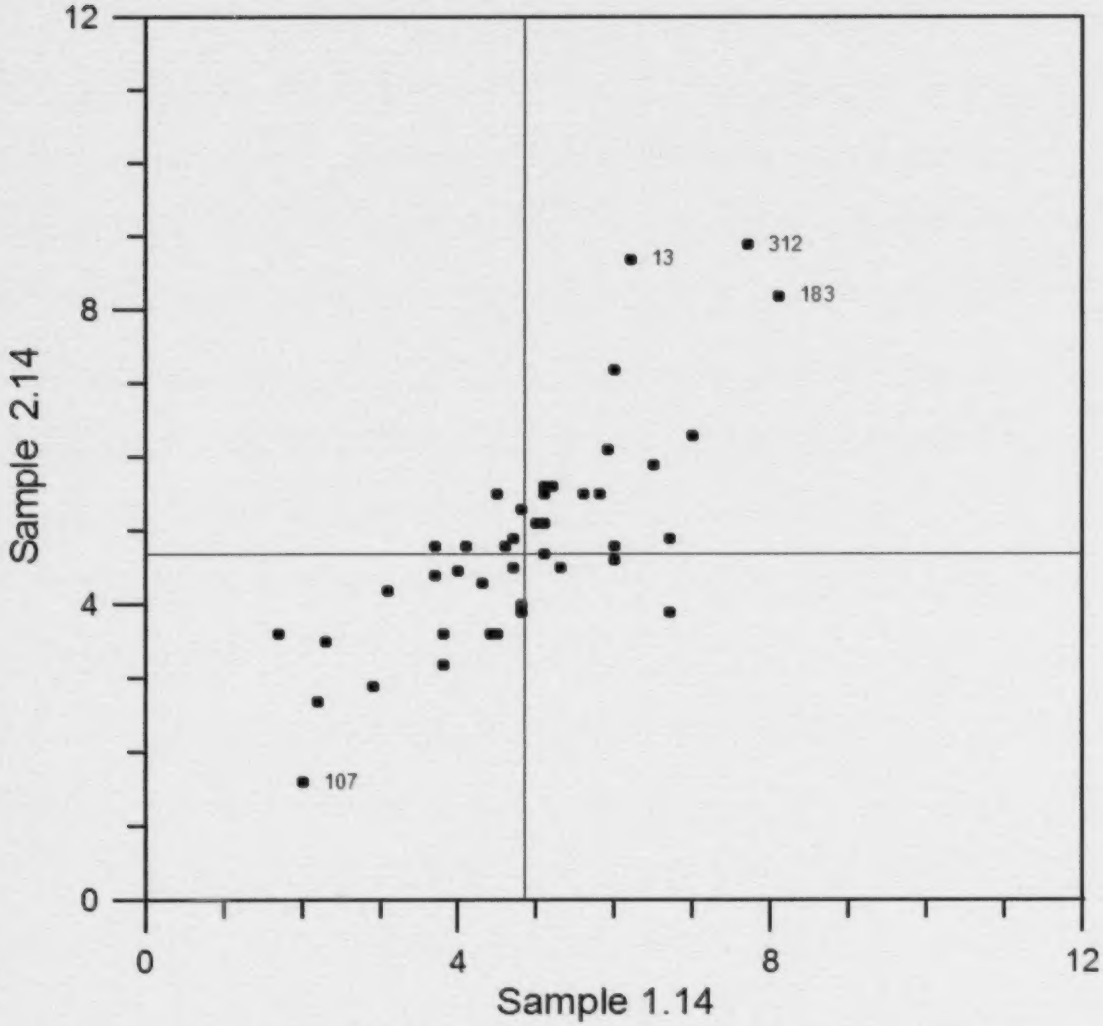
Test 10: Absorption of Coarse Aggregate

	Mat 1	Mat 2
Mean	0.734	0.740
Median	0.729	0.768
Std Dev	0.078	0.079

n = 94

Labs Eliminated: 54; 80; 149; 205; 235

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



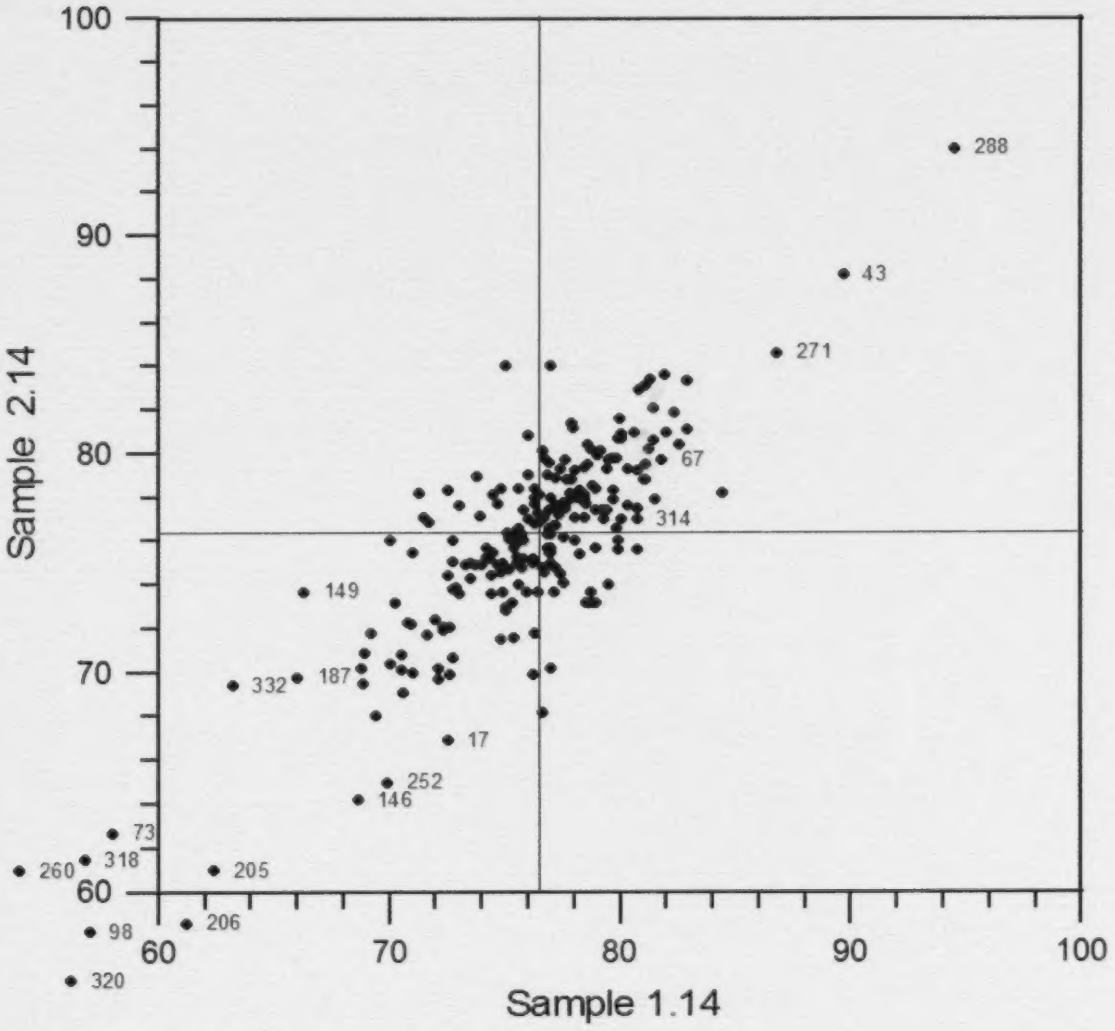
Test 11: MgSO4 Soundness of Coarse Aggregate, % Loss

	Mat 1	Mat 2
Mean	4.851	4.692
Median	4.350	4.950
Std Dev	1.442	0.976

n = 39

Labs Eliminated: 13; 107; 183; 312

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



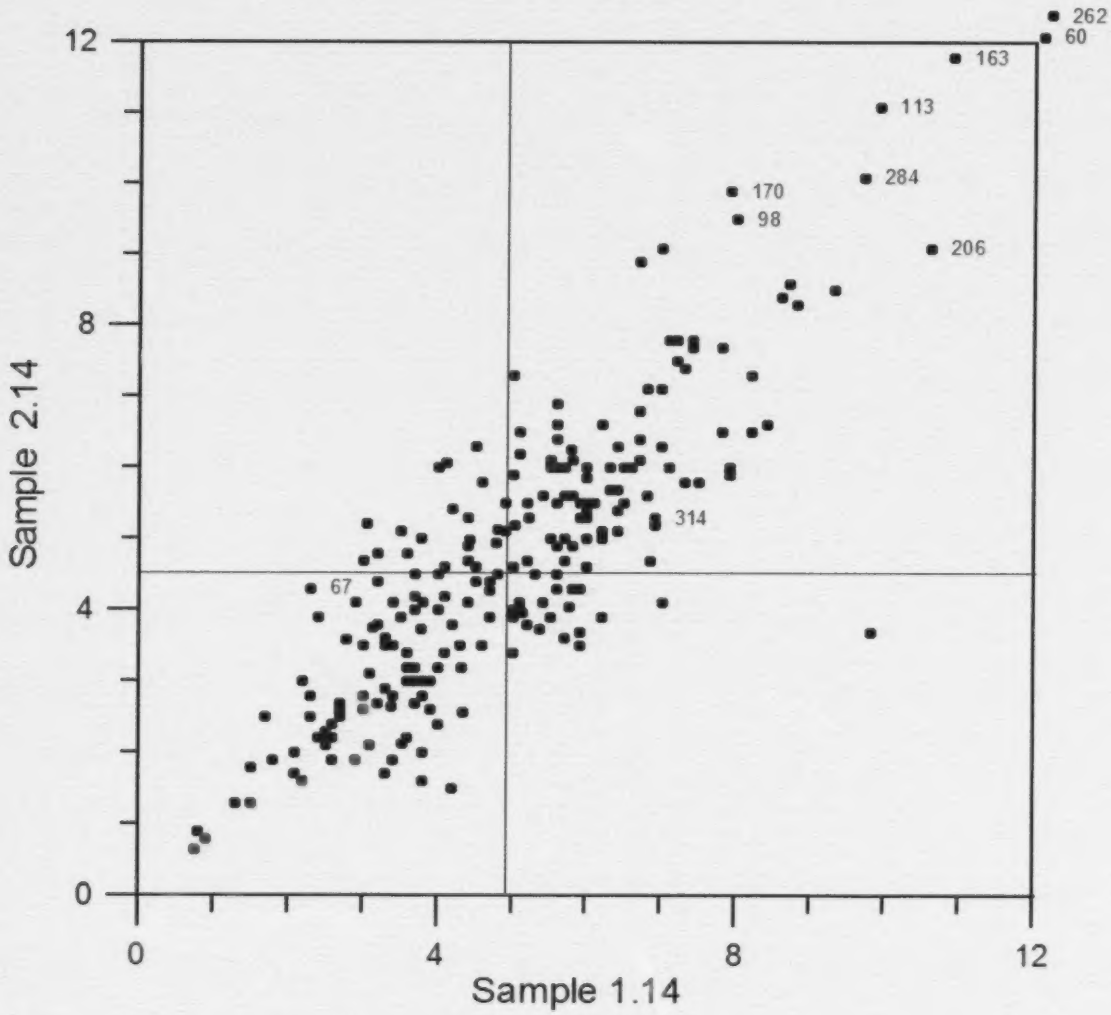
Test 12: Percent Crushed Particles

	Mat 1	Mat 2
Mean	76.418	76.415
Median	76.600	76.000
Std Dev	3.226	3.343

n = 208

Labs Eliminated: 17; 43; 67; 73; 98; 146; 149; 187; 205; 206; 252; 260 271; 288; 314; 318; 320; 332

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



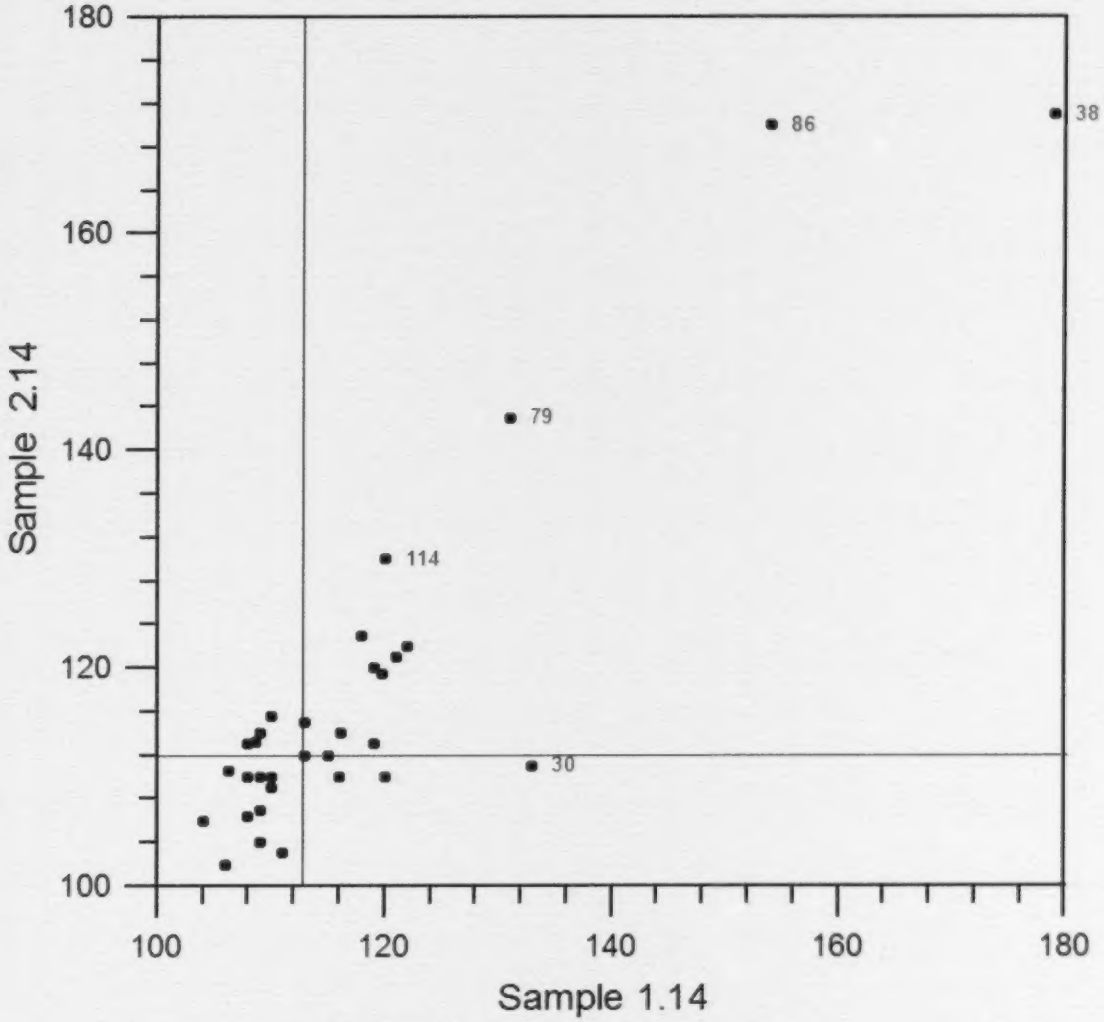
Test 13: Percent Flat and Elongated Particles

	Mat 1	Mat 2
Mean	4.888	4.533
Median	5.275	4.870
Std Dev	1.811	1.752

n = 216

Labs Eliminated: 60; 67; 98; 113; 163; 170; 206; 262; 284; 314

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



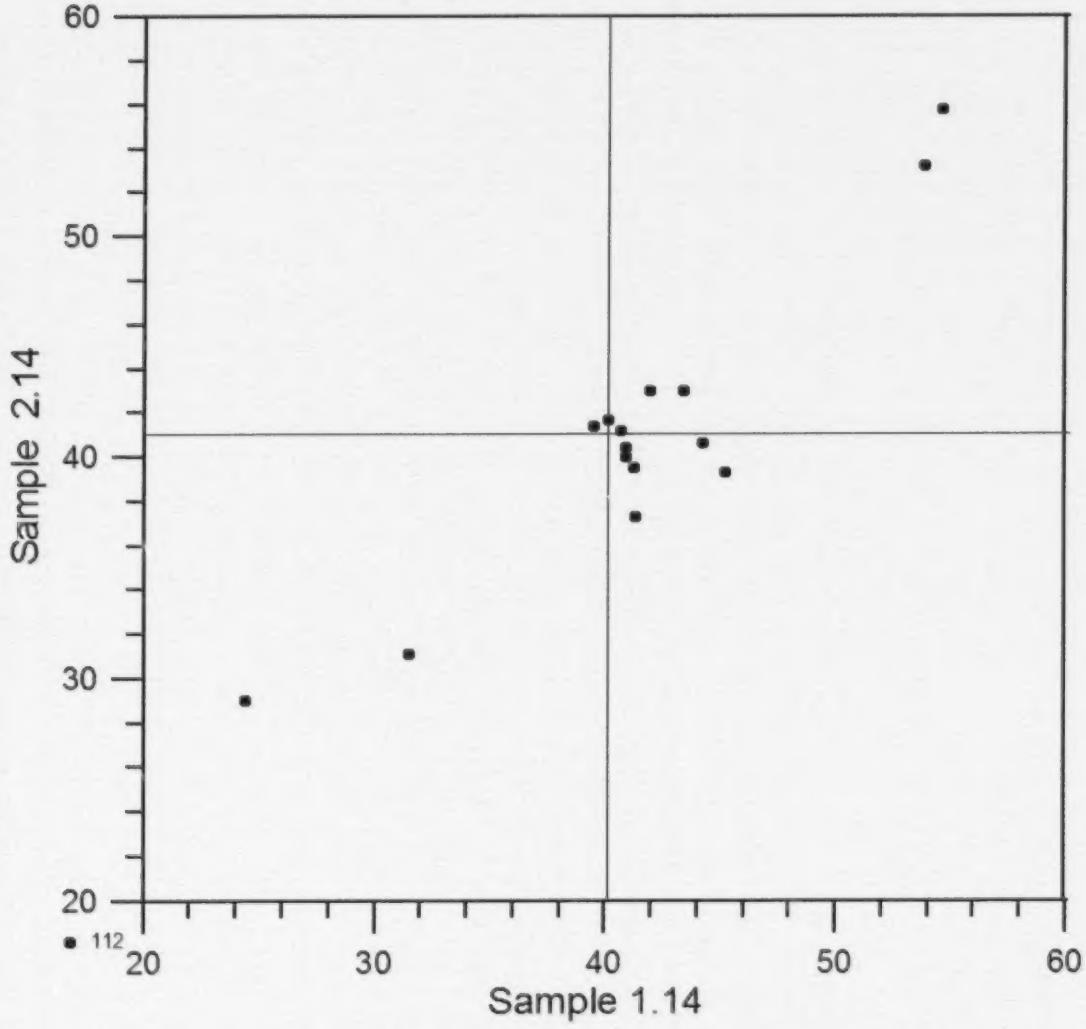
Test 14: Petrographic Number (Concrete)

	Mat 1	Mat 2
Mean	112.8	112.0
Median	113.0	112.5
Std Dev	5.3	5.4

n = 28

Labs Eliminated: 30; 38; 79; 86; 114

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



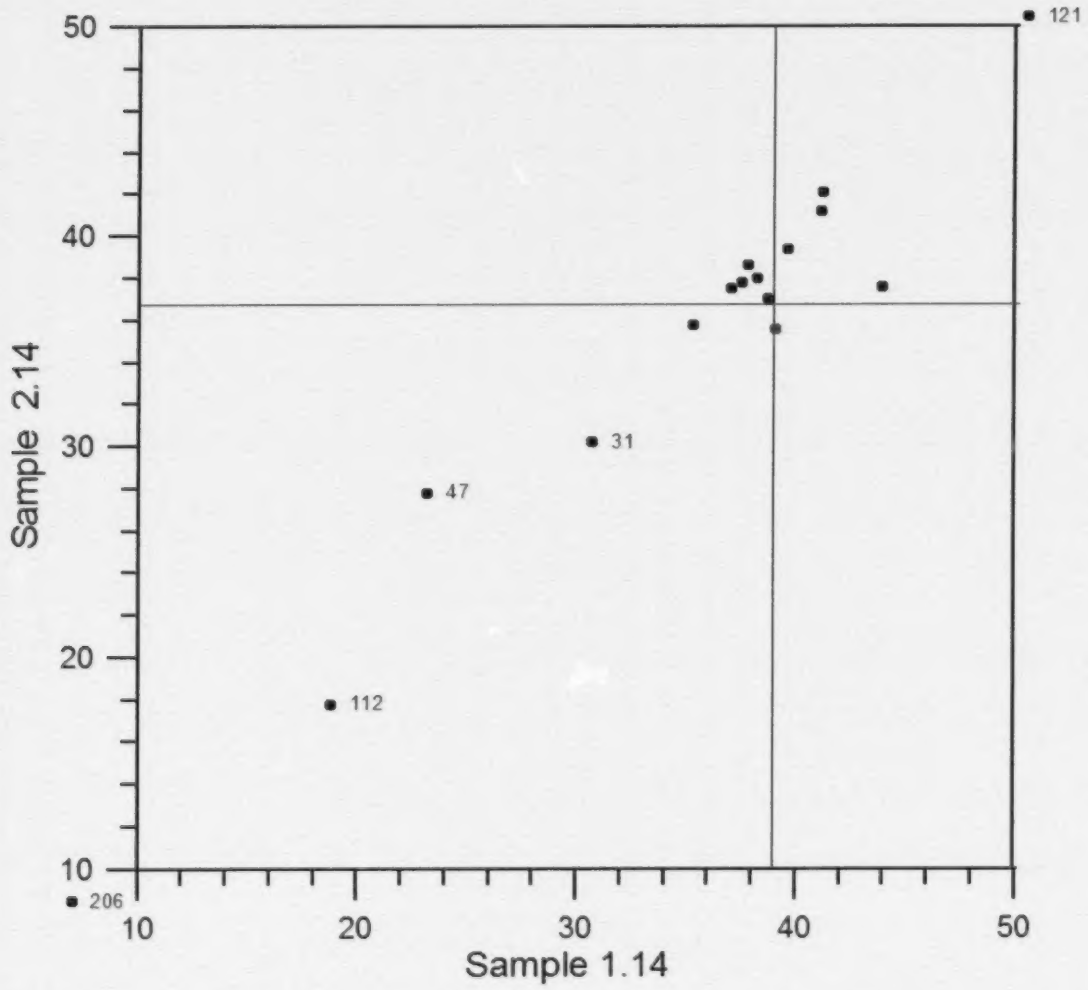
Test 15: Total Percentage of Insoluble Residue

	Mat 1	Mat 2
Mean	40.188	41.100
Median	39.500	42.400
Std Dev	8.795	6.755

n = 15

Lab Eliminated: 112

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



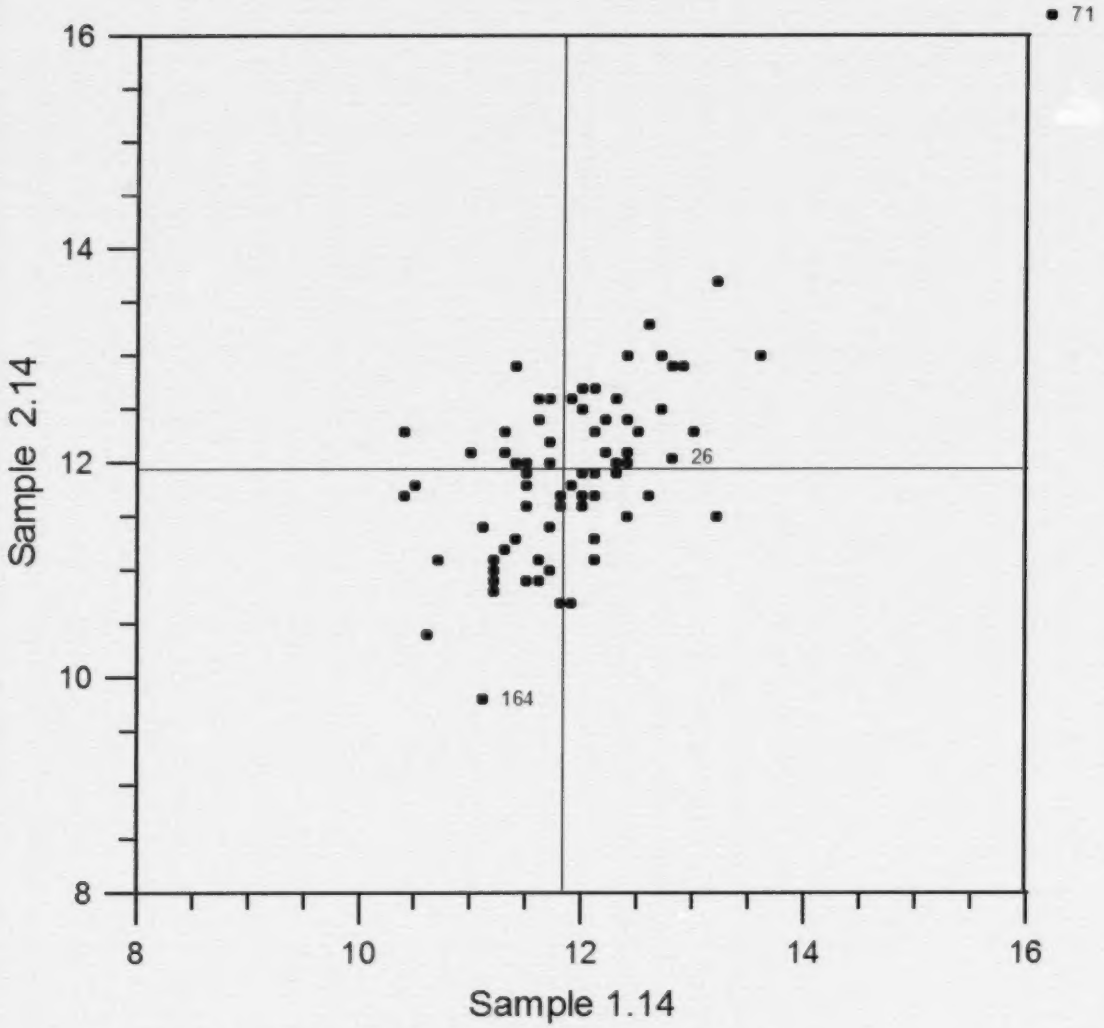
Test 98: Percentage of Insoluble Residue Retained 75µm

	Mat 1	Mat 2
Mean	39.027	36.815
Median	39.600	38.850
Std Dev	2.360	3.959

n = 11

Labs Eliminated: 31; 47; 112; 121; 206

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



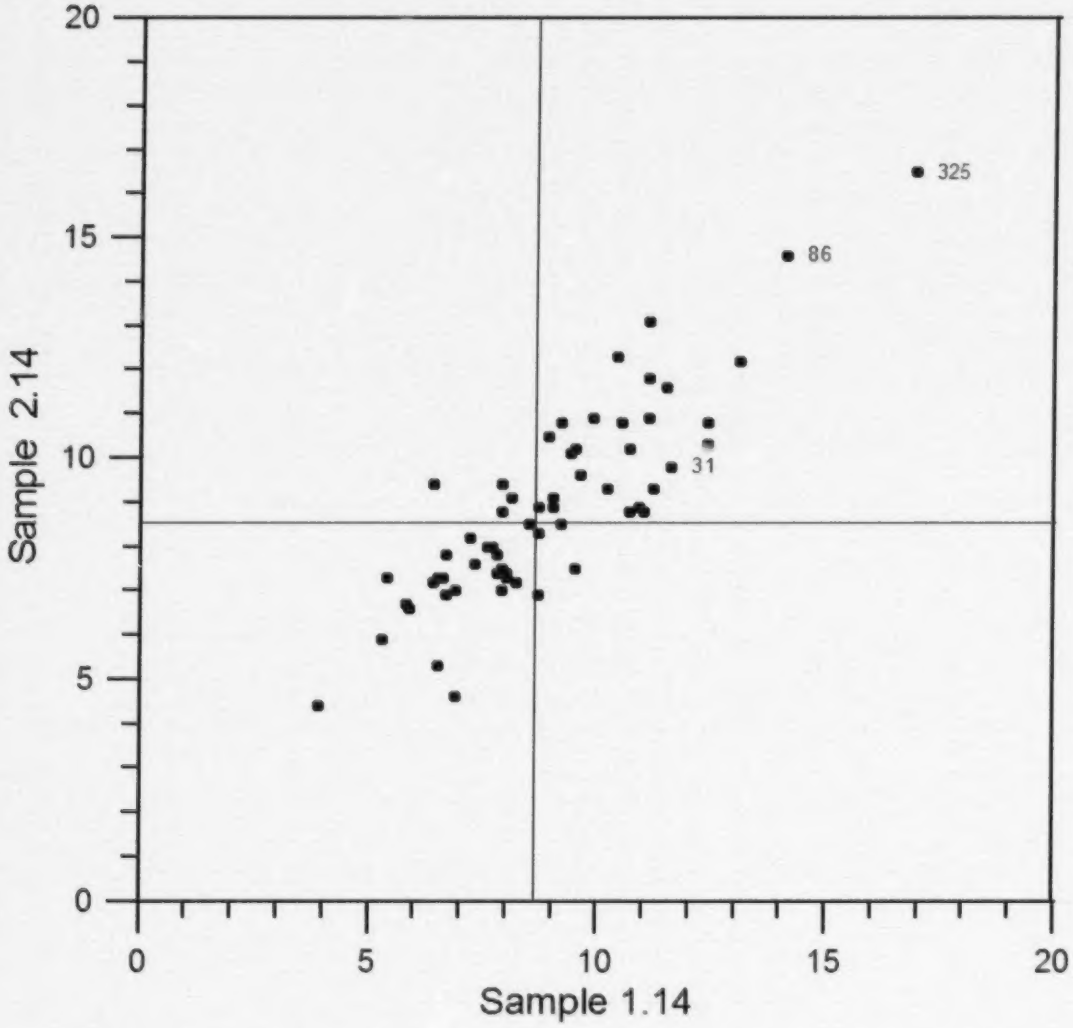
Test 16: Micro-Deval Abrasion Loss (CA), %

	Mat 1	Mat 2
Mean	11.854	11.921
Median	12.000	12.050
Std Dev	0.644	0.688

n = 75

Labs Eliminated: 26; 71; 164

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



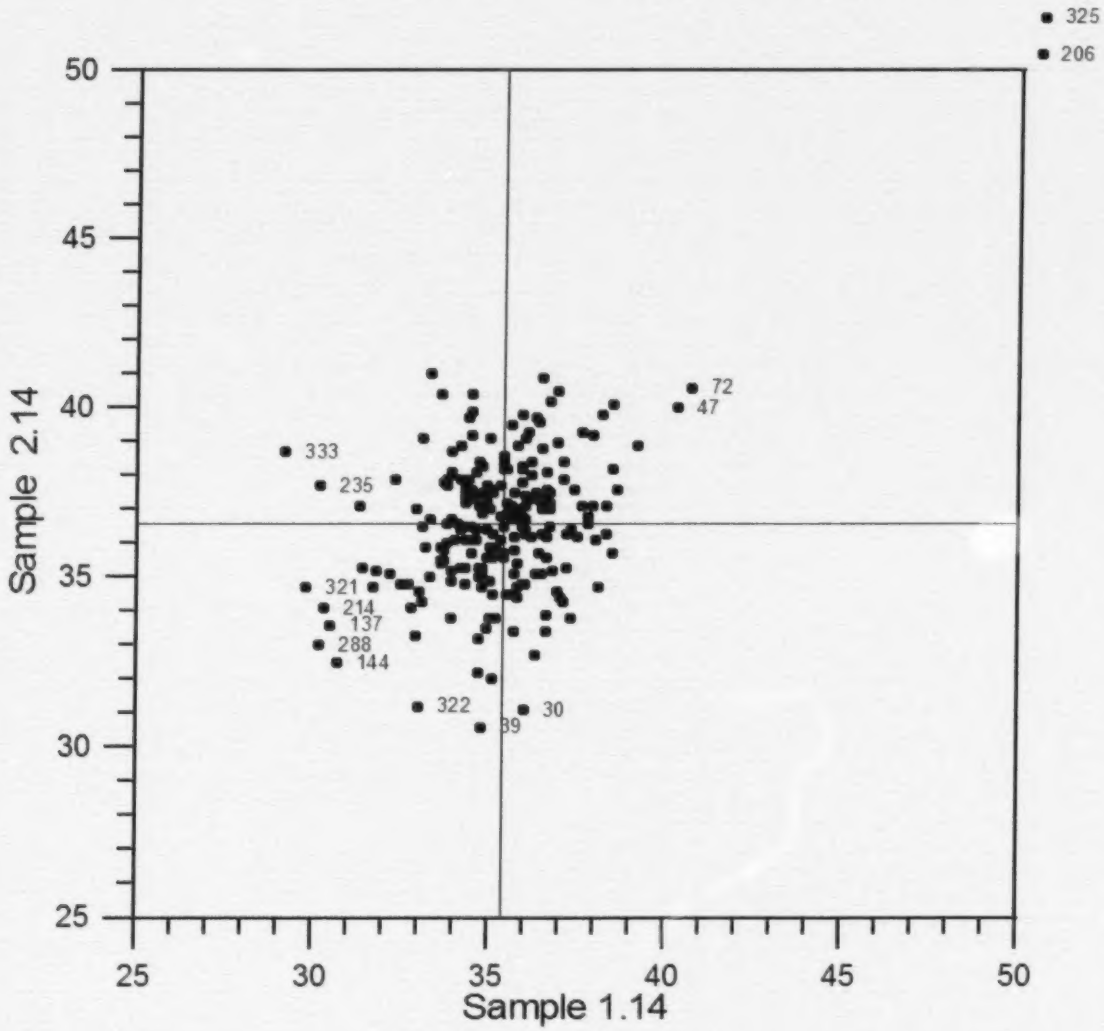
Test 17: Freeze-Thaw Loss, %

	Mat 1	Mat 2
Mean	8.714	8.640
Median	8.500	8.750
Std Dev	2.083	1.868

n = 58

Labs Eliminated: 31; 86; 325

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



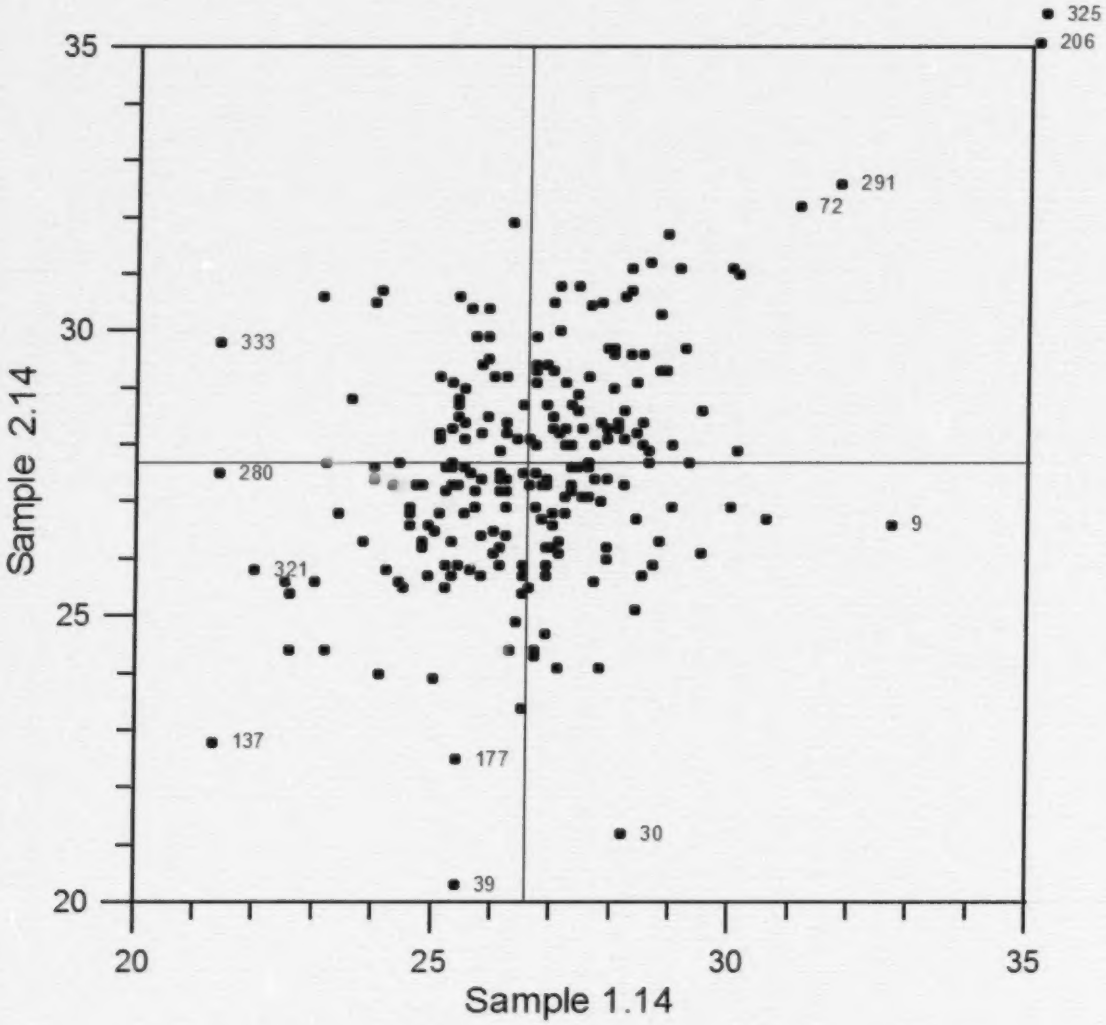
Test 20: Percent Passing the 2.36 mm Sieve

	Mat 1	Mat 2
Mean	35.334	36.639
Median	35.250	36.500
Std Dev	1.475	1.808

n = 212

Labs Eliminated: 30; 39; 47; 72; 137; 144; 206; 214; 235; 288; 321; 322; 325; 333

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



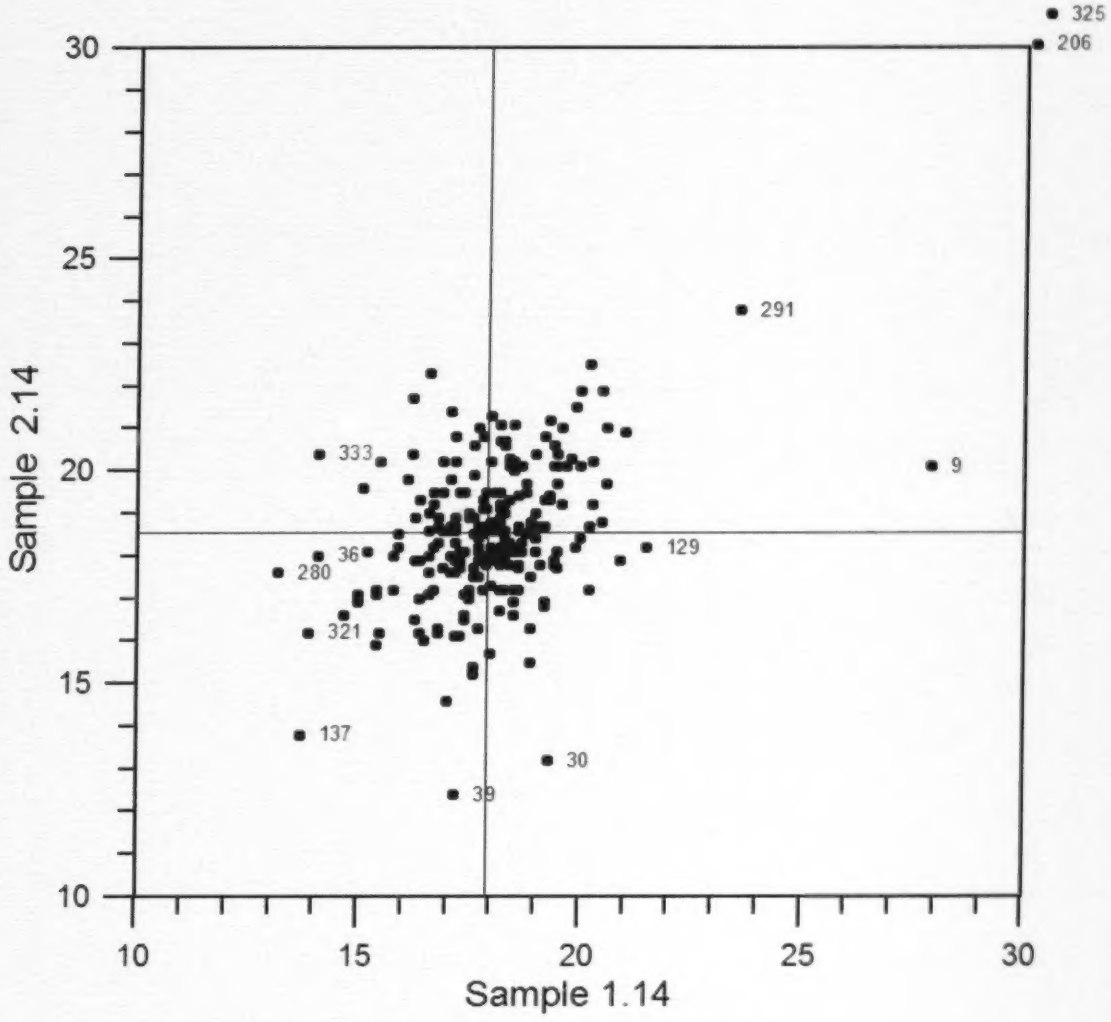
Test 21: Percent Passing the 1.18 mm Sieve

	Mat 1	Mat 2
Mean	26.595	27.666
Median	26.550	27.650
Std Dev	1.568	1.792

n = 214

Labs Eliminated: 9; 30; 39; 72; 137; 177; 206; 280; 291; 321; 325; 333

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



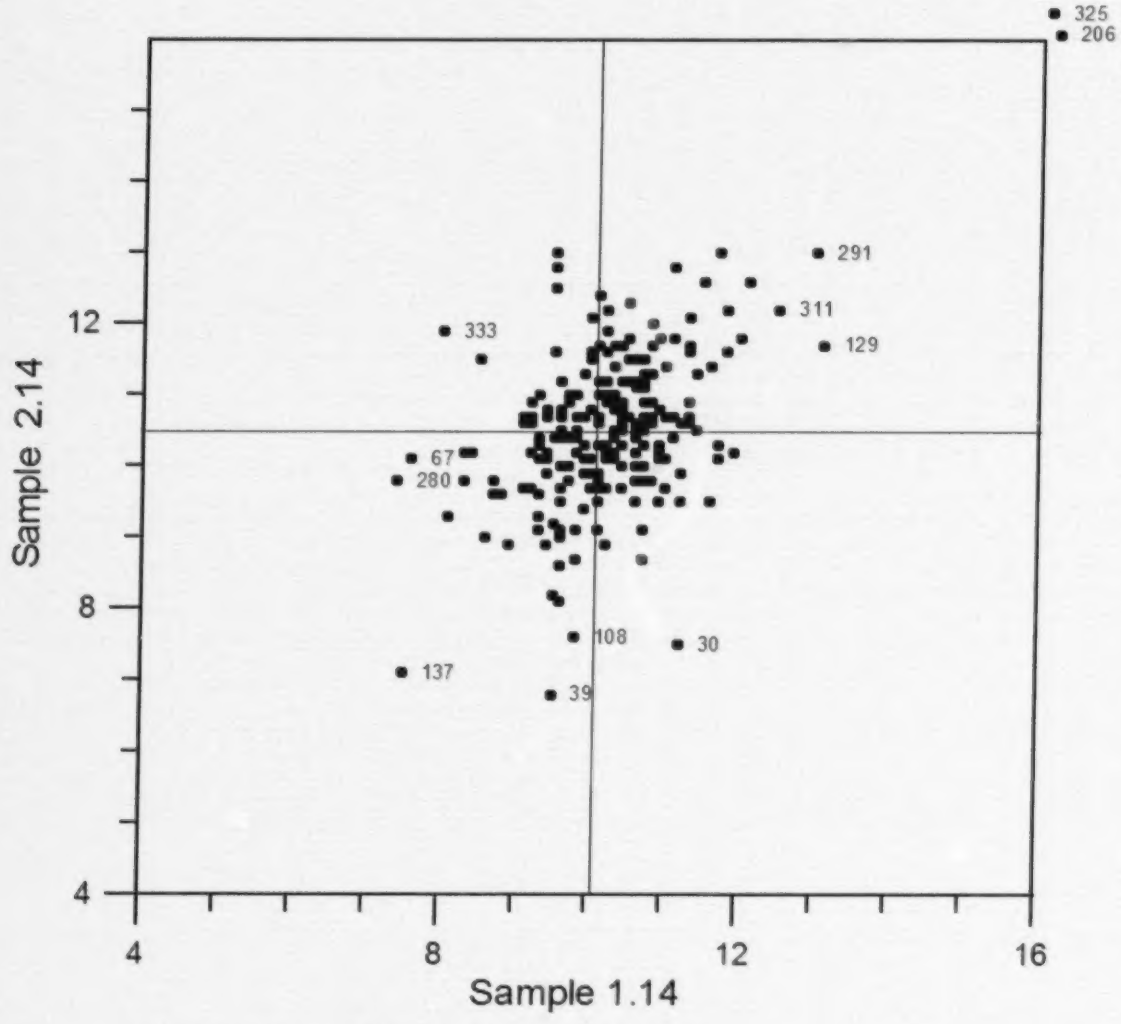
Test 22: Percent Passing the 600 um Sieve

	Mat 1	Mat 2
Mean	17.940	18.570
Median	17.850	18.550
Std Dev	1.243	1.453

n = 214

Labs Eliminated: 9; 30; 36; 39; 129; 137; 206; 280; 291; 321; 325; 333

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



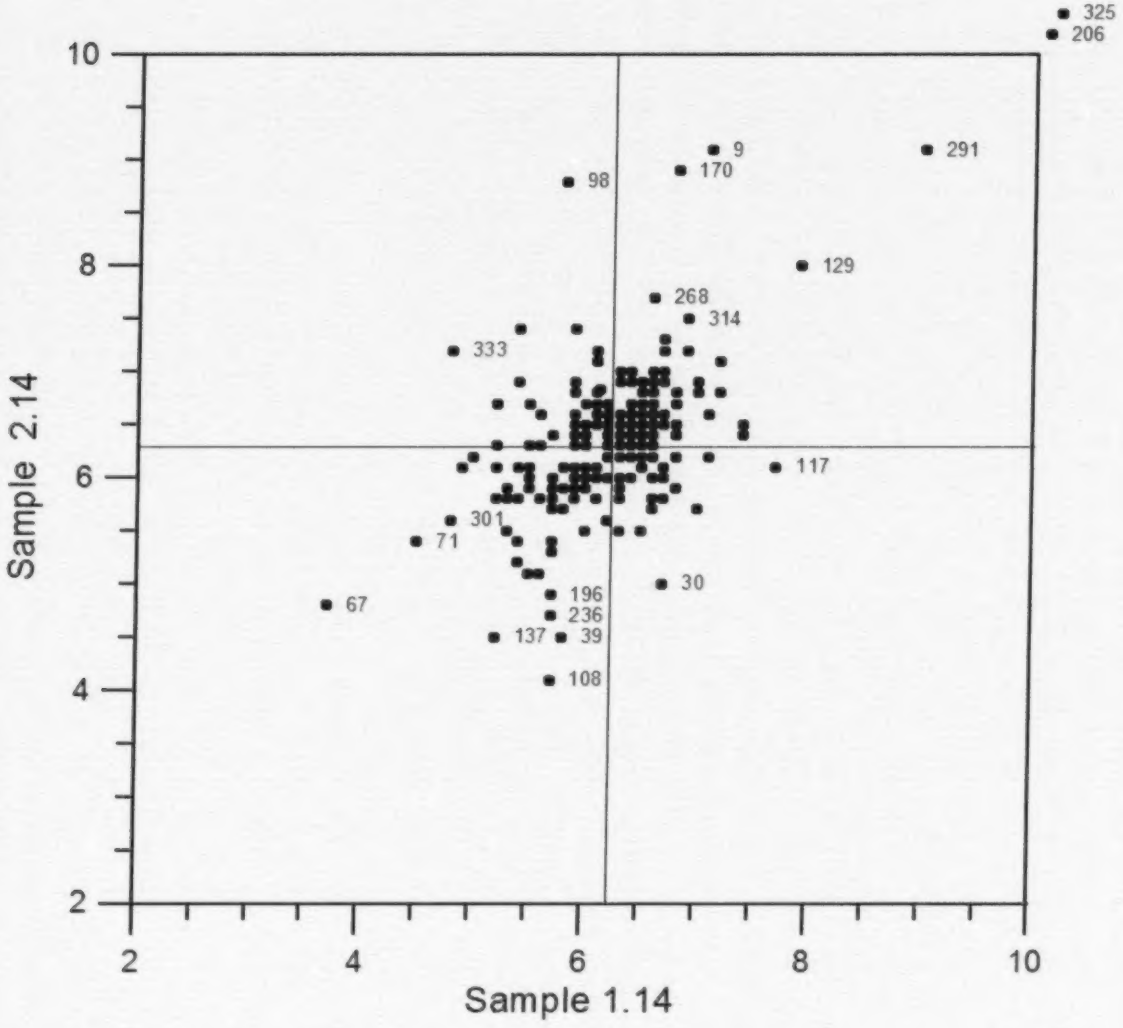
Test 23: Percent Passing the 300 um Sieve

	Mat 1	Mat 2
Mean	10.206	10.548
Median	10.100	10.550
Std Dev	0.777	0.919

n = 214

Labs Eliminated: 30; 39; 67; 108; 129; 137; 206; 280; 291; 311; 325; 333

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



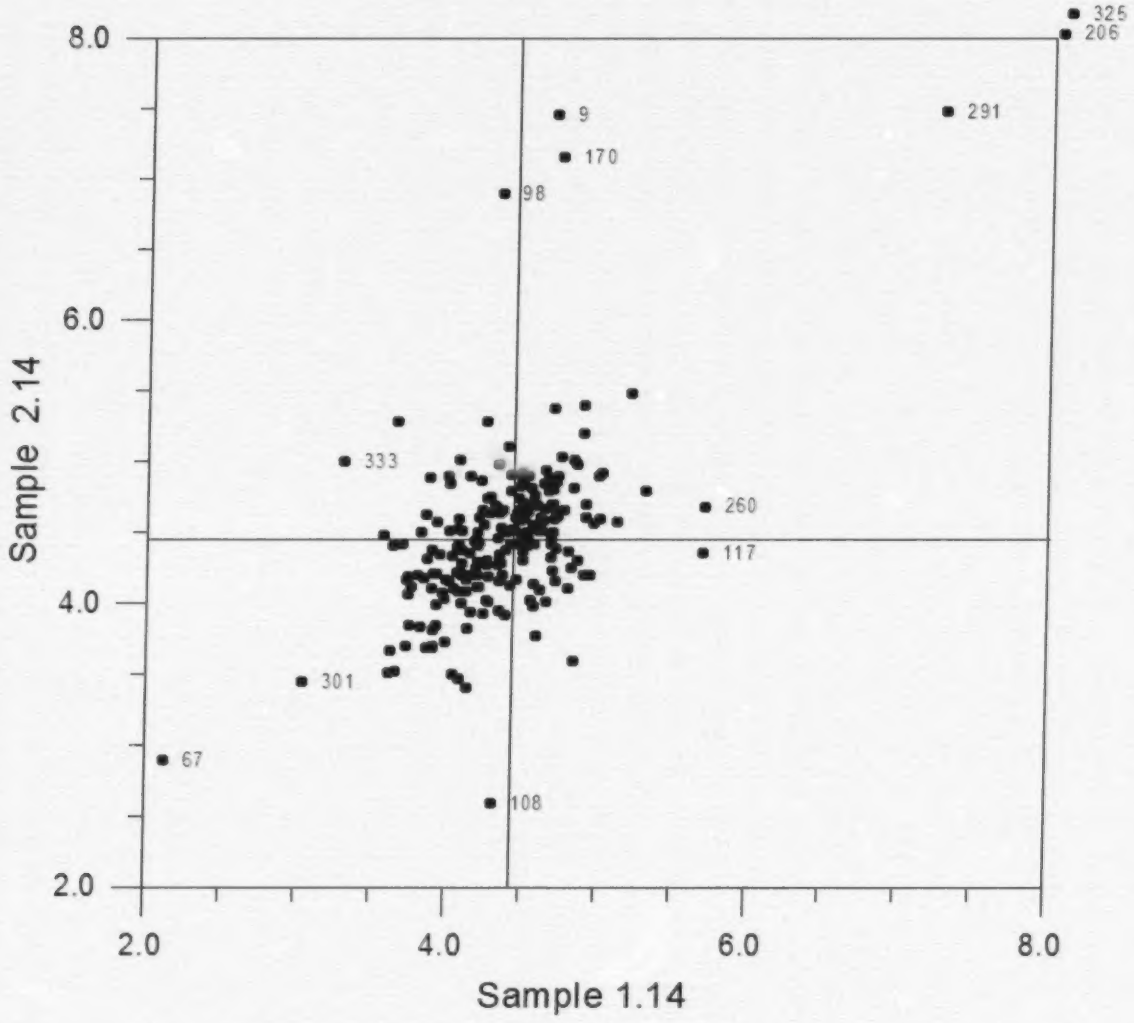
Test 24: Percent Passing the 150 um Sieve

	Mat 1	Mat 2
Mean	6.191	6.324
Median	6.150	6.250
Std Dev	0.482	0.464

n = 206

Labs Eliminated: 9; 30; 39; 67; 71; 98; 108; 117; 129; 137; 170; 196 206; 236; 268; 291; 301; 314; 325; 333

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



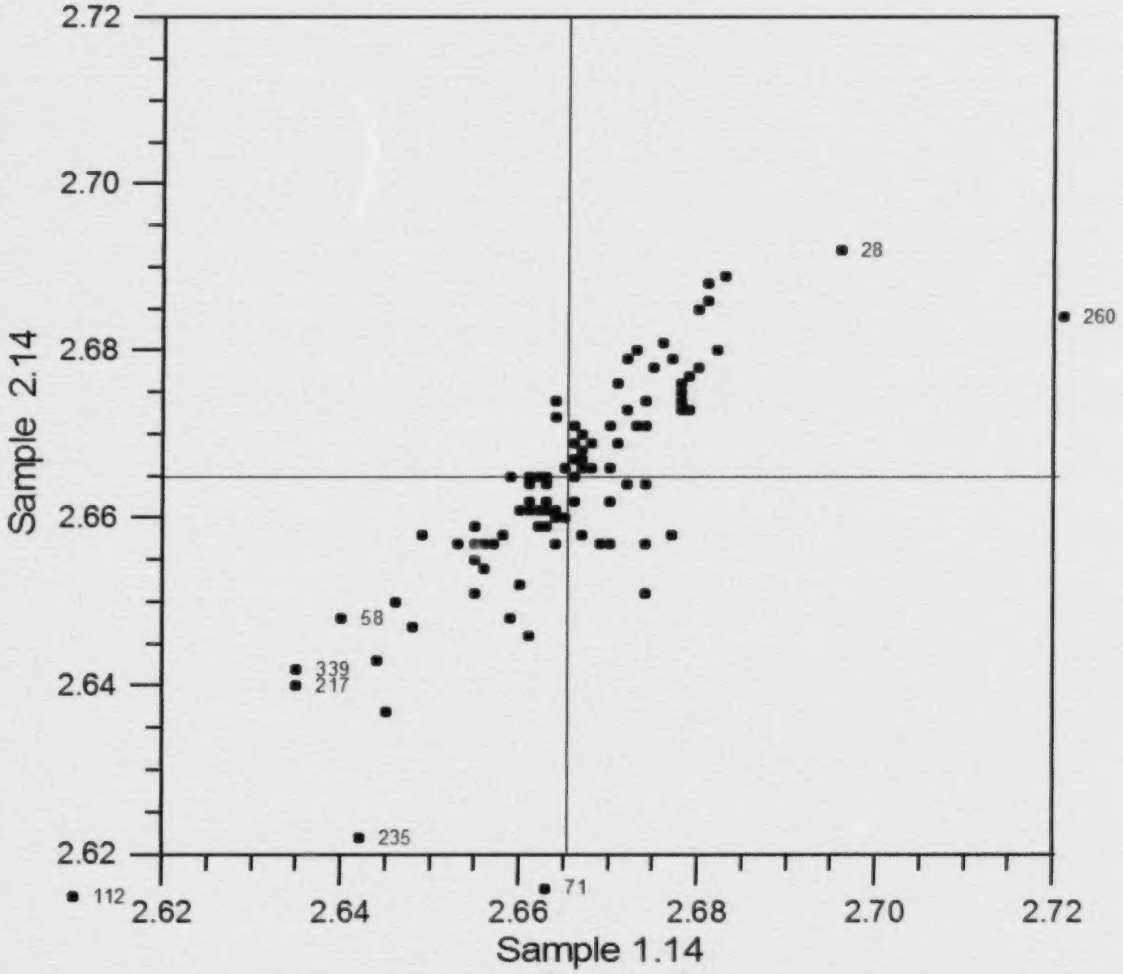
Test 25: Percent Passing the 75 um Sieve

	Mat 1	Mat 2
Mean	4.360	4.429
Median	4.445	4.440
Std Dev	0.349	0.387

n = 213

Labs Eliminated: 9; 67; 98; 108; 117; 170; 206; 260; 291; 301; 325; 333

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



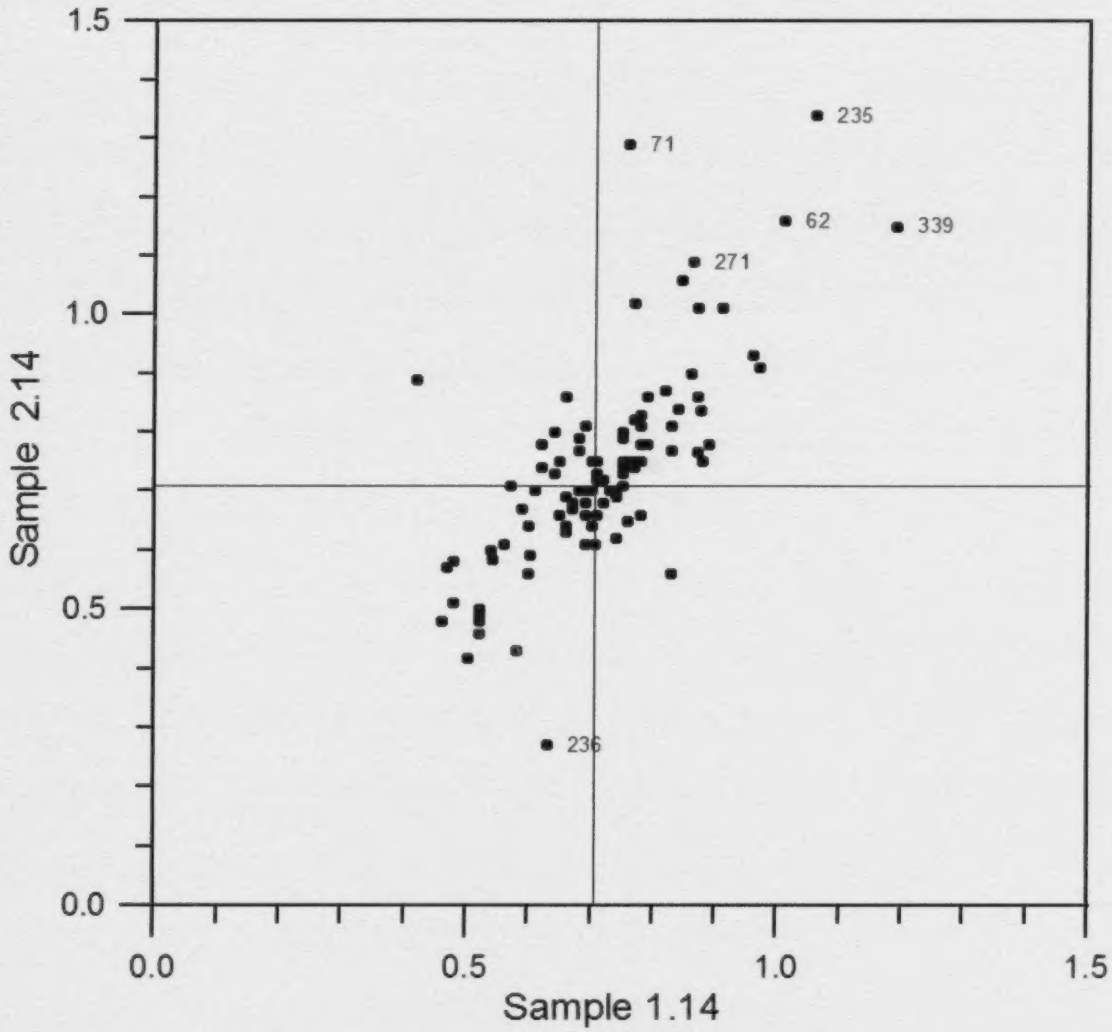
Test 27: Relative Density of Fine Aggregate (O. D)

	Mat 1	Mat 2
Mean	2.666	2.665
Median	2.664	2.663
Std Dev	0.009	0.011

n = 90

Labs Eliminated: 28; 58; 71; 112; 217; 235; 260; 339

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



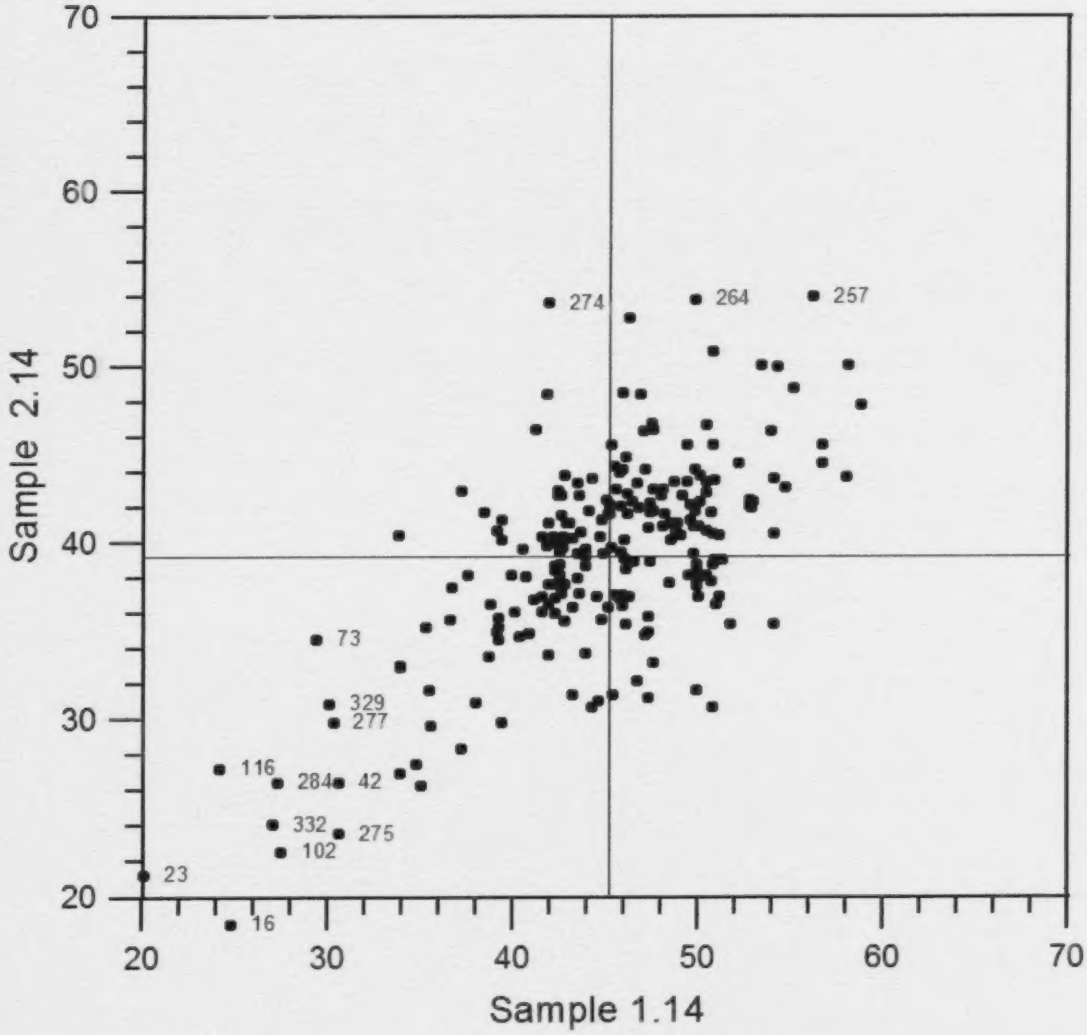
Test 28: Absorption of Fine Aggregate

	Mat 1	Mat 2
Mean	0.709	0.719
Median	0.695	0.738
Std Dev	0.120	0.127

n = 92

Labs Eliminated: 62; 71; 235; 236; 271; 339

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



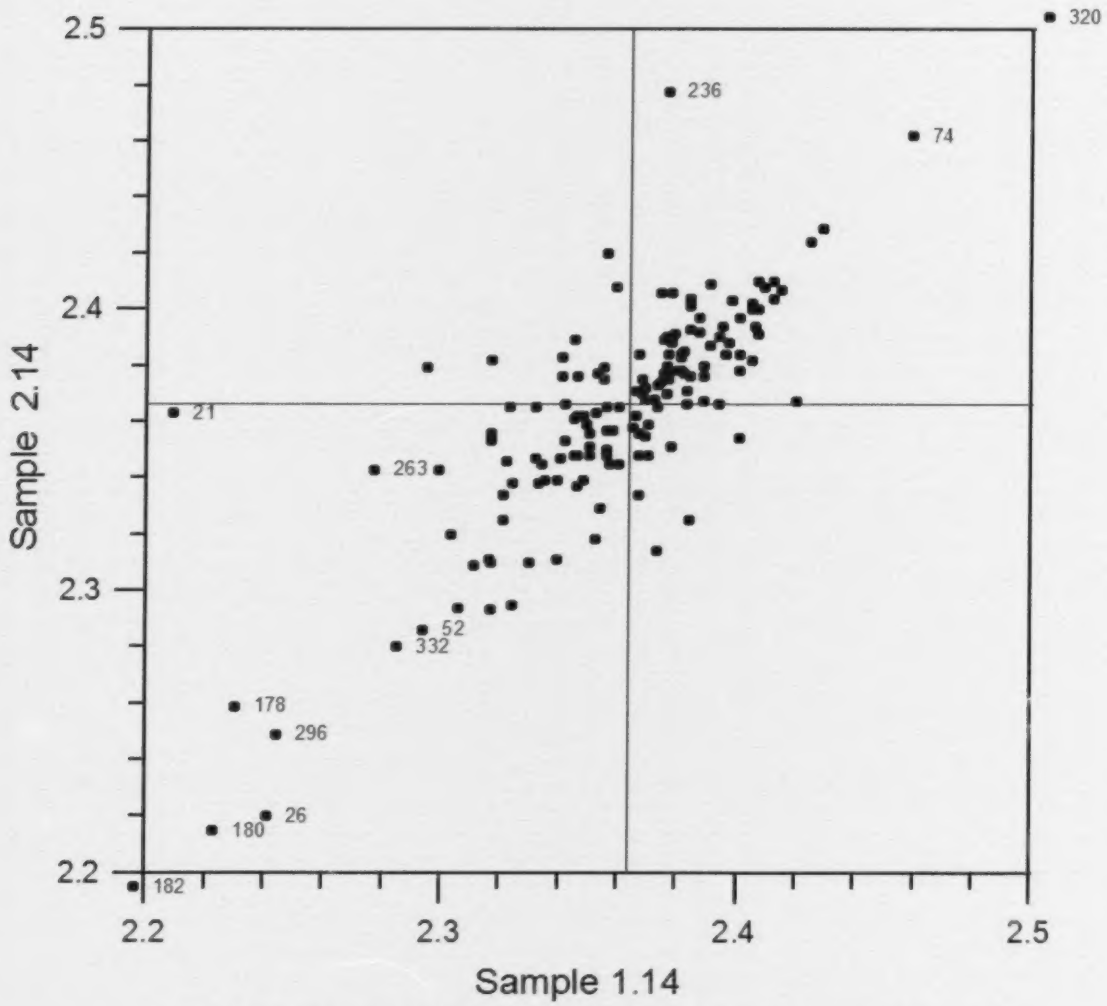
Test 30: Percent Asphalt Coated Particles

	Mat 1	Mat 2
Mean	45.716	39.409
Median	46.300	39.550
Std Dev	5.048	4.861

n = 211

Labs Eliminated: 16; 23; 42; 73; 102; 116; 257; 264; 274; 275; 277; 284; 329; 332

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



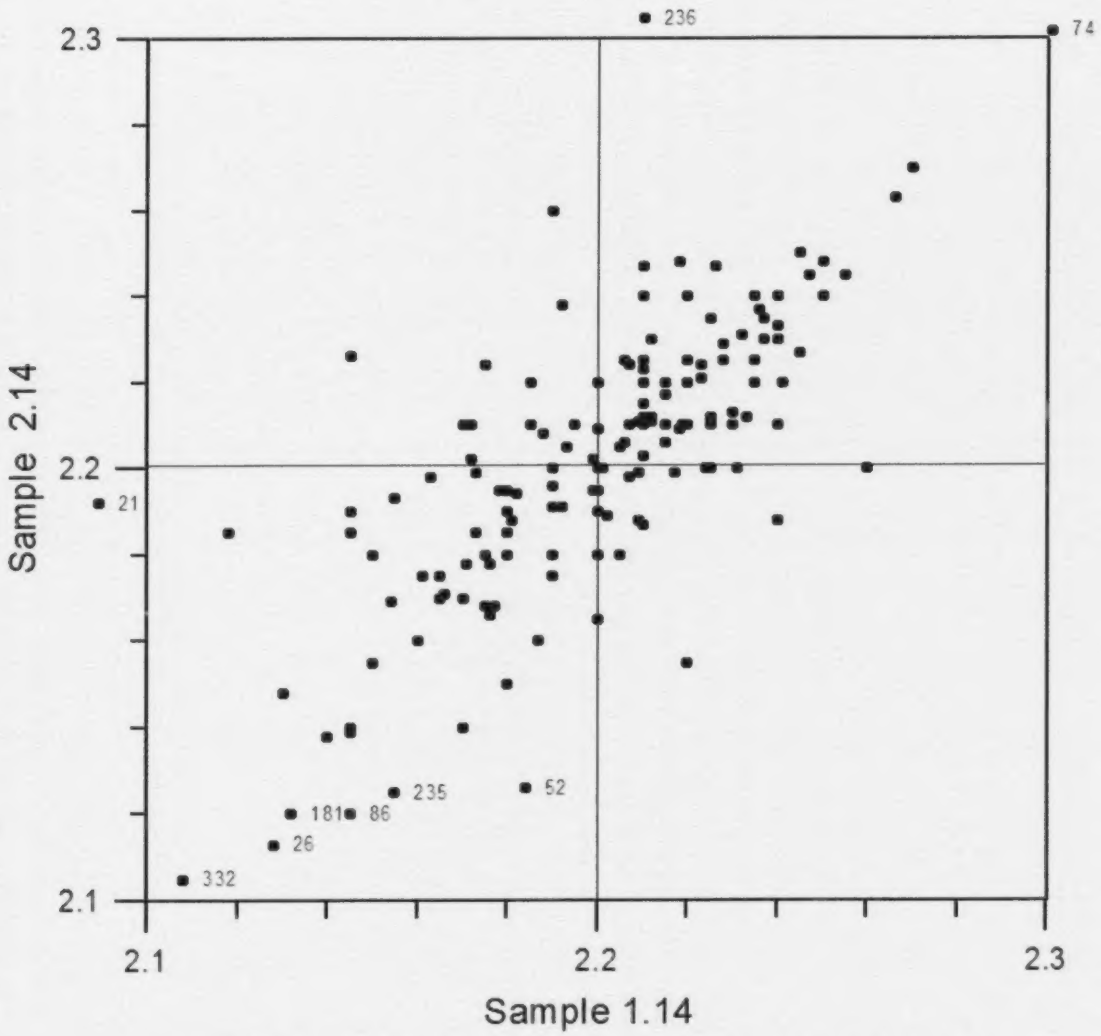
Test 31: Maximum Wet Density g/cm3 (Moisture-Density)

	Mat 1	Mat 2
Mean	2.365	2.367
Median	2.362	2.361
Std Dev	0.029	0.027

n = 144

Labs Eliminated: 21; 26; 52; 74; 178; 180; 182; 236; 263; 296; 320; 332

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



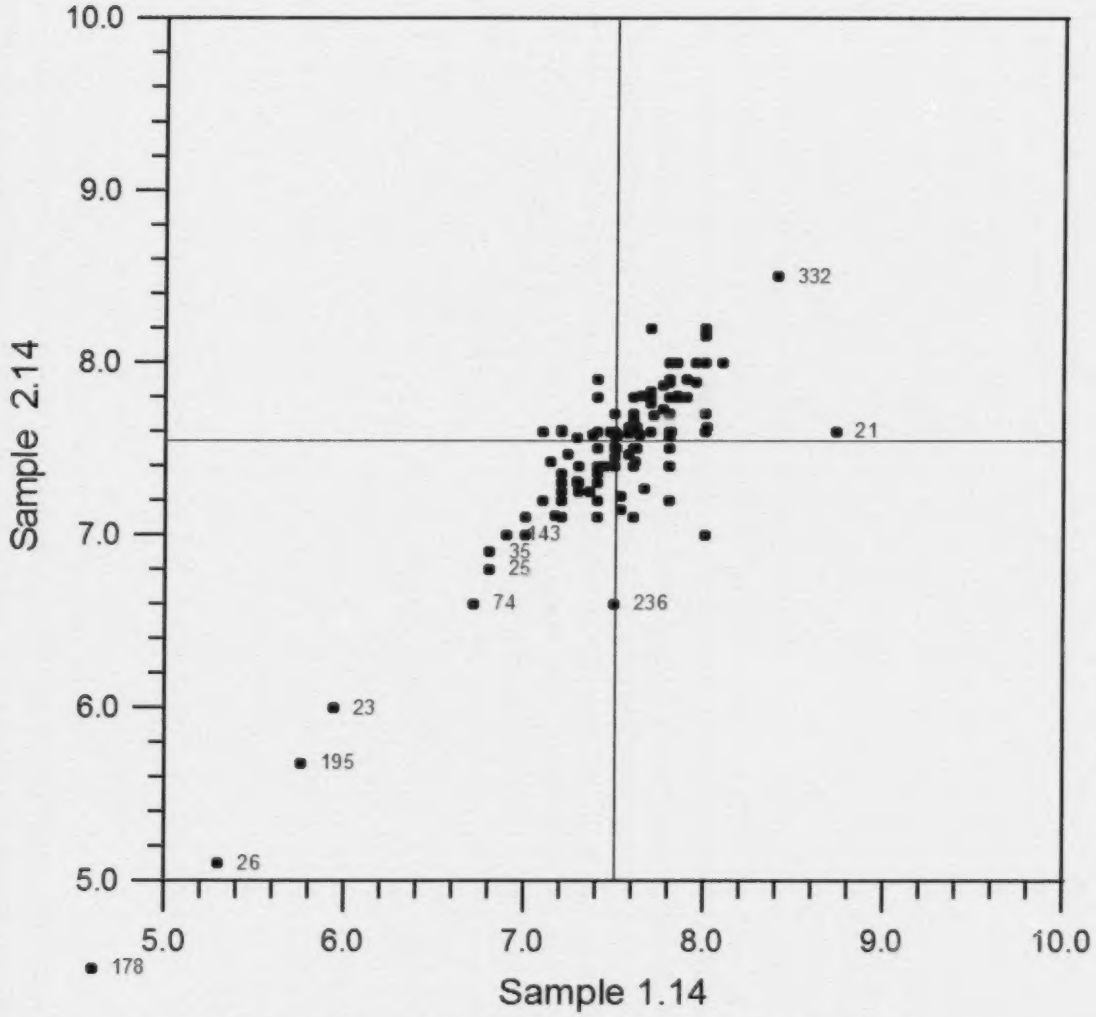
Test 32: Maximum Dry Density g/cm3 (Moisture-Density)

	Mat 1	Mat 2
Mean	2.200	2.204
Median	2.194	2.204
Std Dev	0.030	0.026

n = 147

Labs Eliminated: 21; 26; 52; 74; 86; 181; 235; 236; 332

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



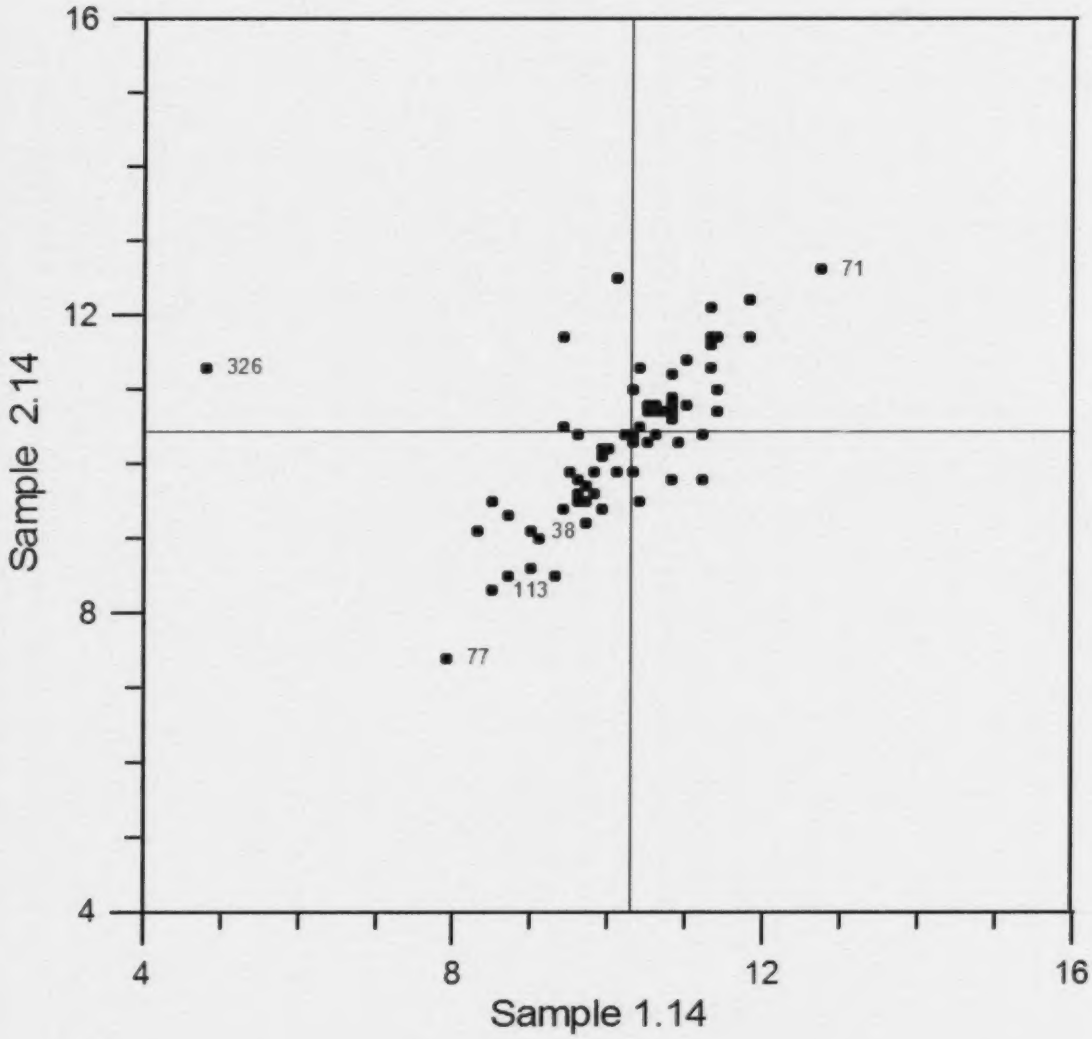
Test 33: Optimum Moisture, % (Moisture - Density)

	Mat 1	Mat 2
Mean	7.573	7.550
Median	7.550	7.600
Std Dev	0.235	0.256

n = 145

Labs Eliminated: 21; 23; 25; 26; 35; 74; 143; 178; 195; 236; 332

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



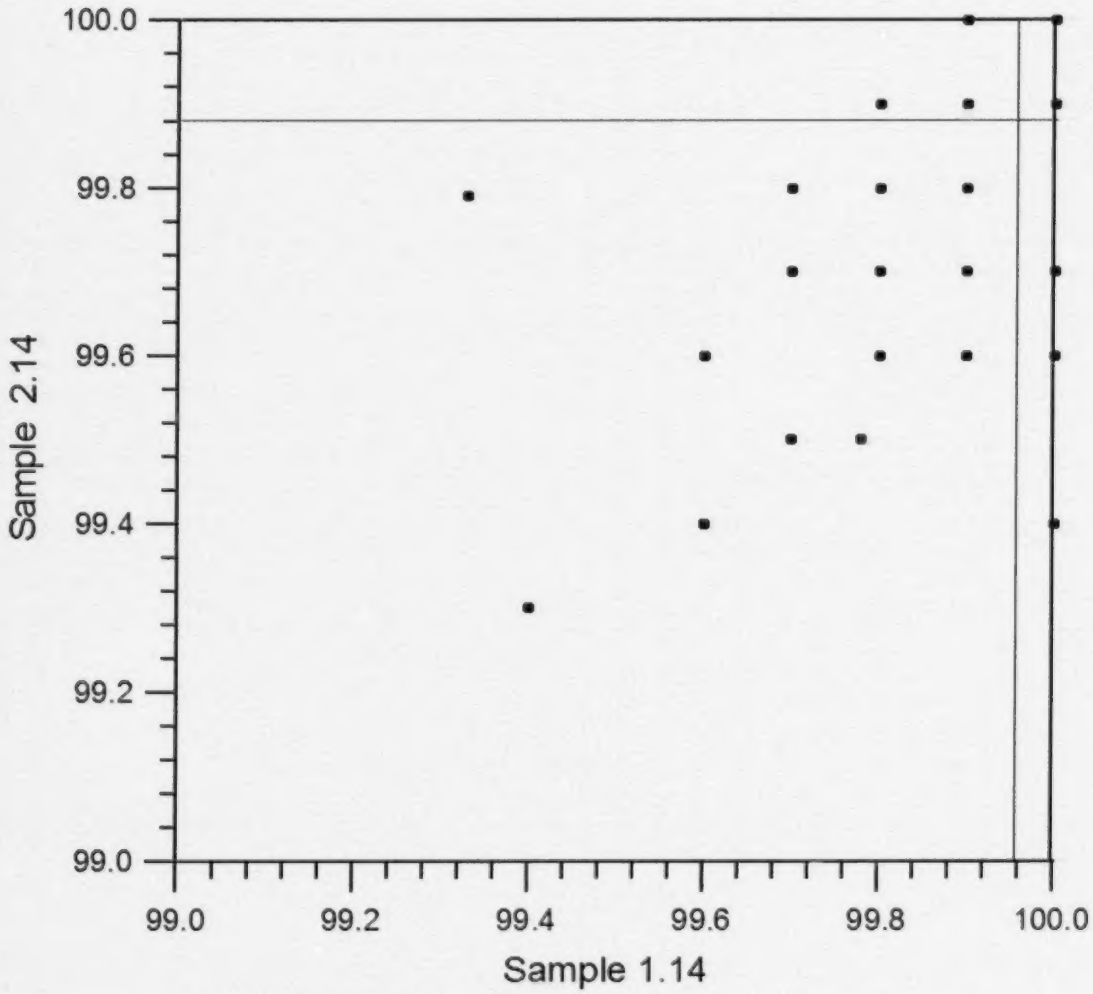
Test 34: Micro-Deval Abrasion Loss (FA), %

	Mat 1	Mat 2
Mean	10.271	10.415
Median	10.050	10.500
Std Dev	0.770	0.886

n = 73

Labs Eliminated: 38; 71; 77; 113; 326

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



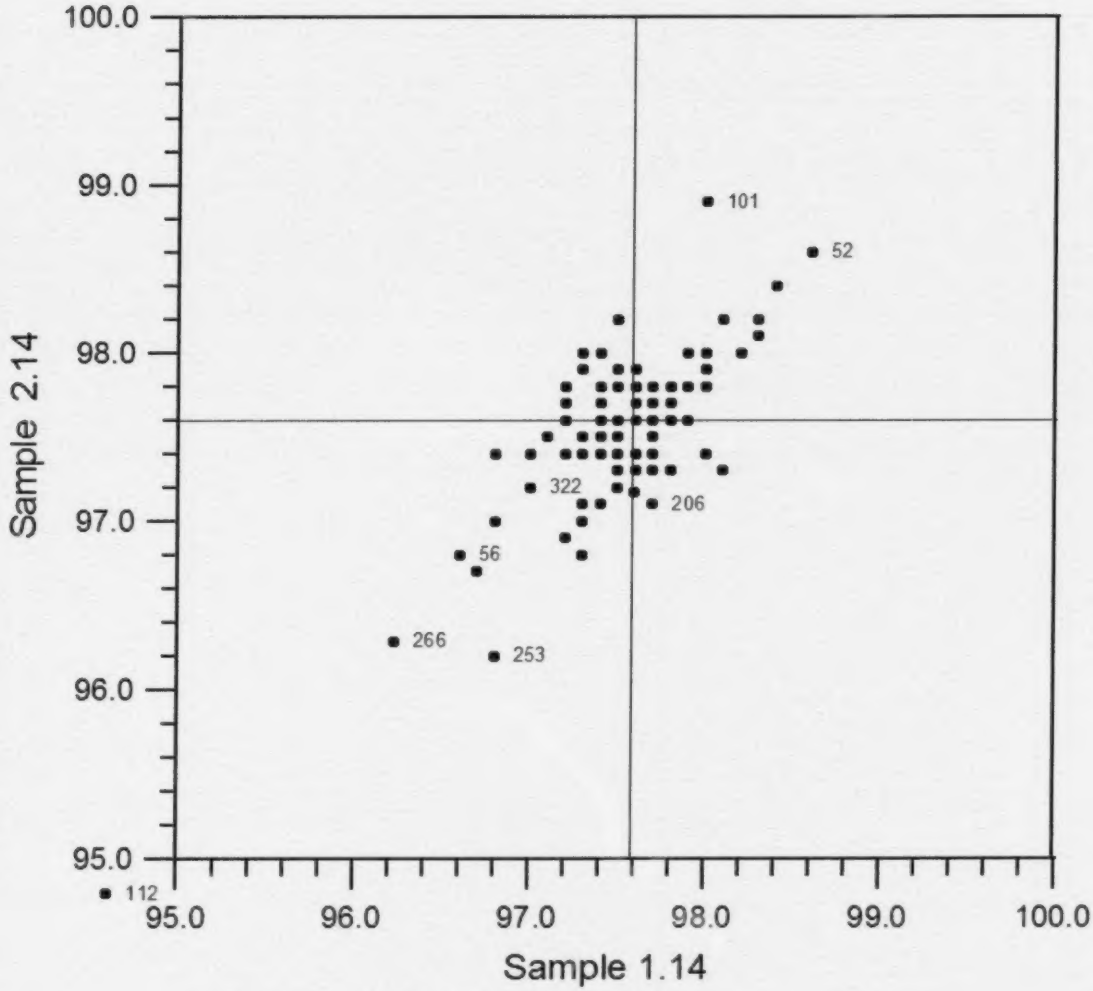
Test 40: Percent Passing the 2.00 mm Sieve (Soil)

	Mat 1	Mat 2
Mean	99.875	99.840
Median	99.665	99.650
Std Dev	0.124	0.148

n = 88

Labs Eliminated: None

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



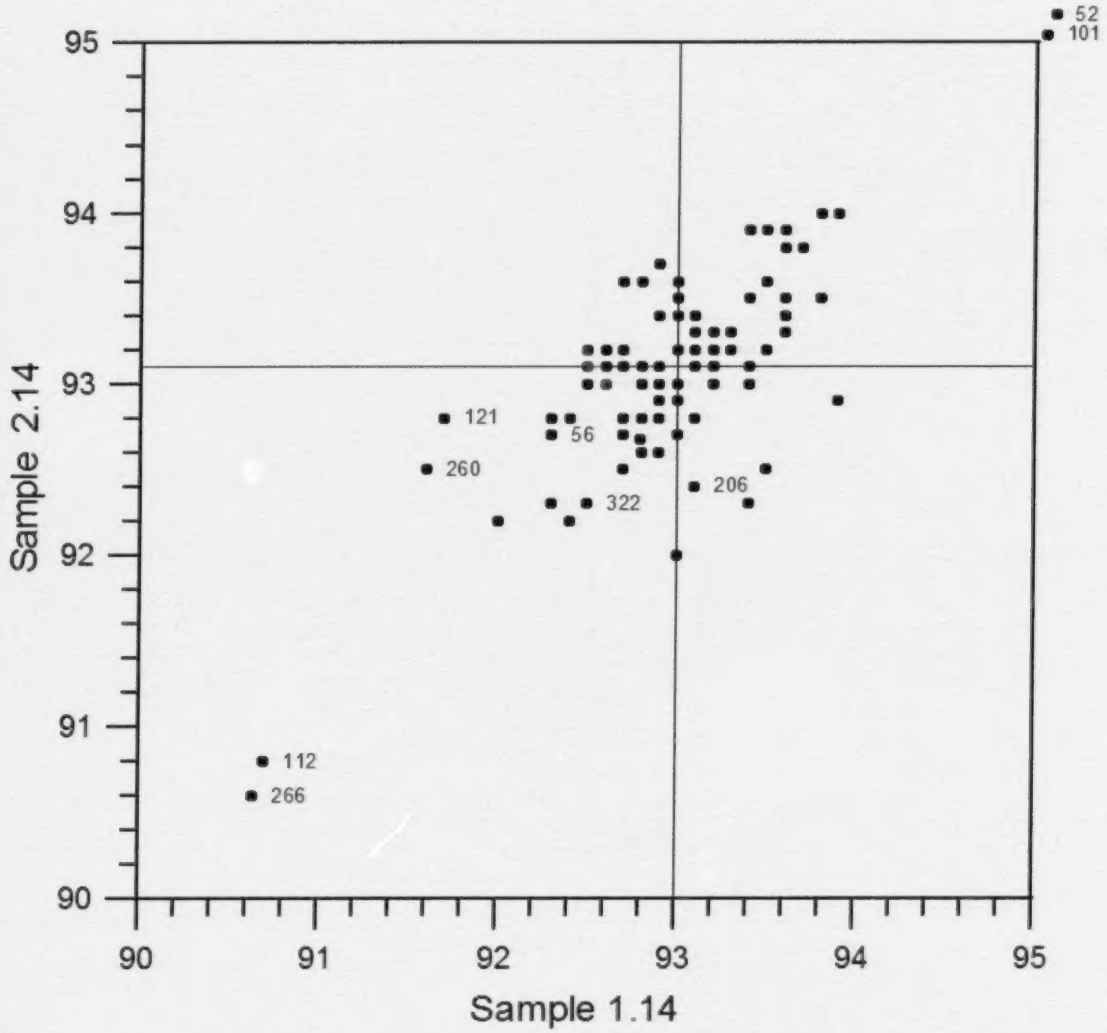
Test 41: Percent Passing the 425 μm Sieve (Soil)

	Mat 1	Mat 2
Mean	97.575	97.616
Median	97.550	97.550
Std Dev	0.353	0.342

n = 80

Labs Eliminated: 52; 56; 101; 112; 206; 253; 266; 322

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



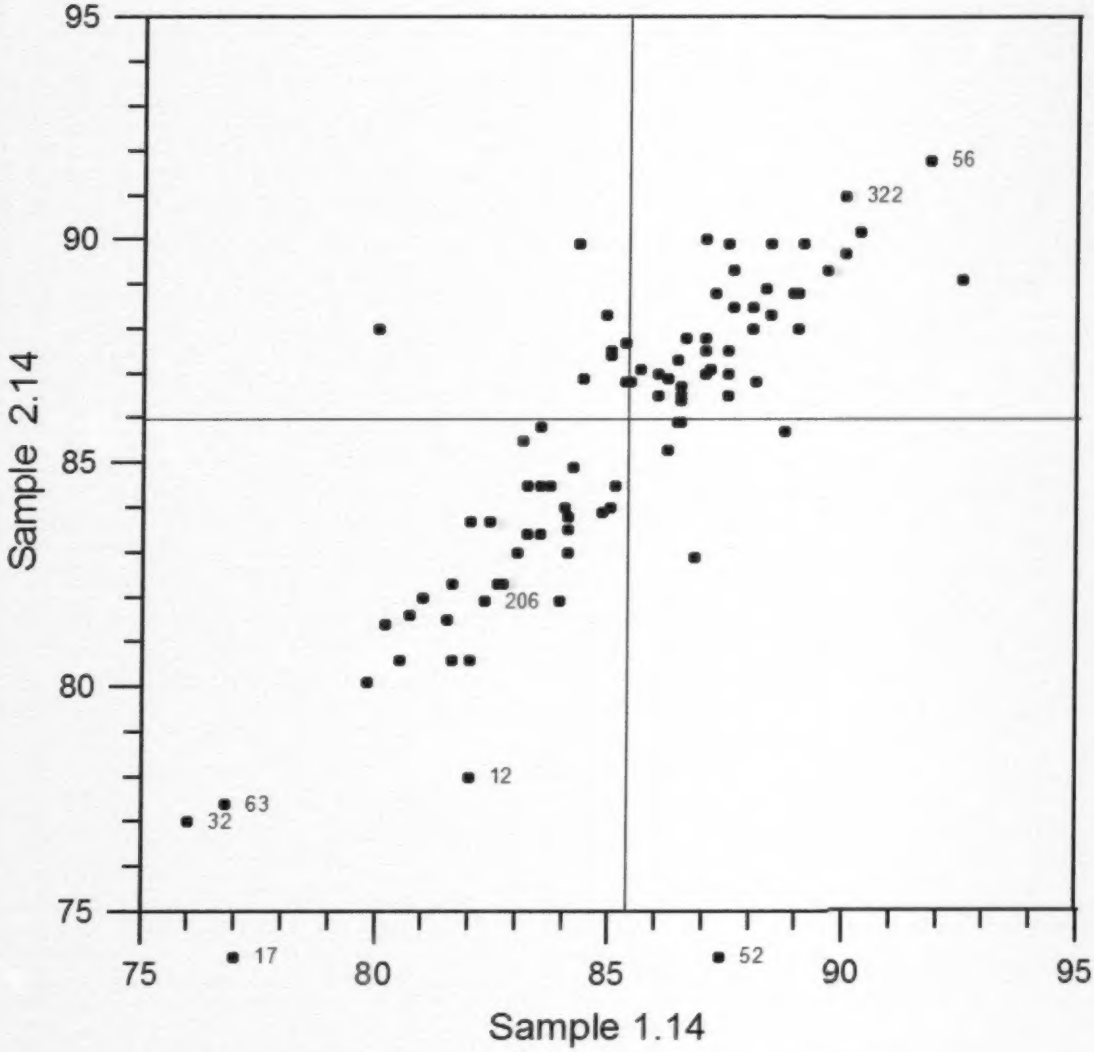
Test 42: Percent Passing the 75 μm Sieve (Soil)

	Mat 1	Mat 2
Mean	93.002	93.097
Median	92.950	93.000
Std Dev	0.412	0.425

n = 79

Labs Eliminated: 52; 56; 101; 112; 121; 206; 260; 266; 322

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



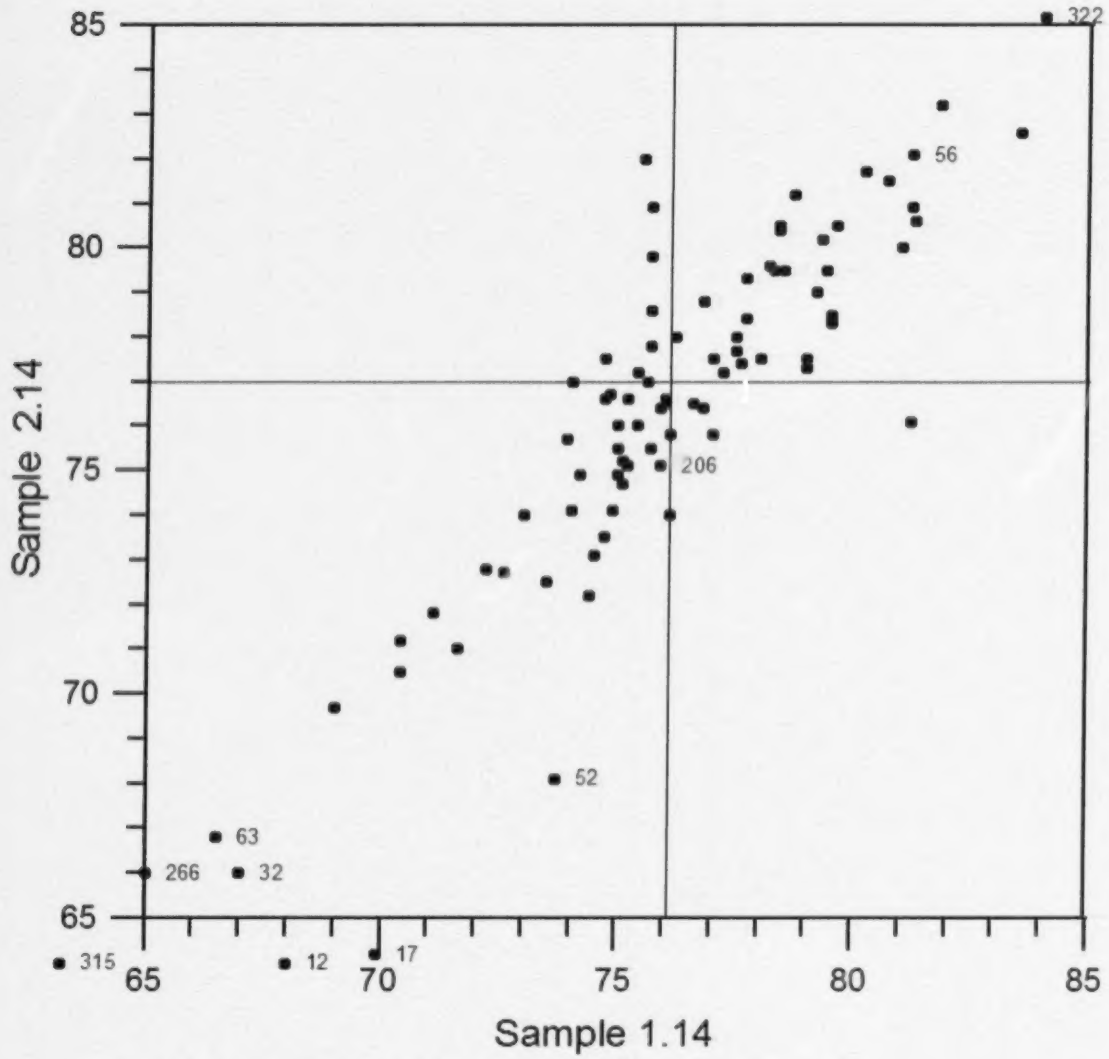
Test 43: Percent Passing the 20 μm Sieve (Soil)

	Mat 1	Mat 2
Mean	85.452	85.951
Median	86.150	85.150
Std Dev	2.703	2.711

n = 80

Labs Eliminated: 12; 17; 32; 52; 56; 63; 206; 322

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



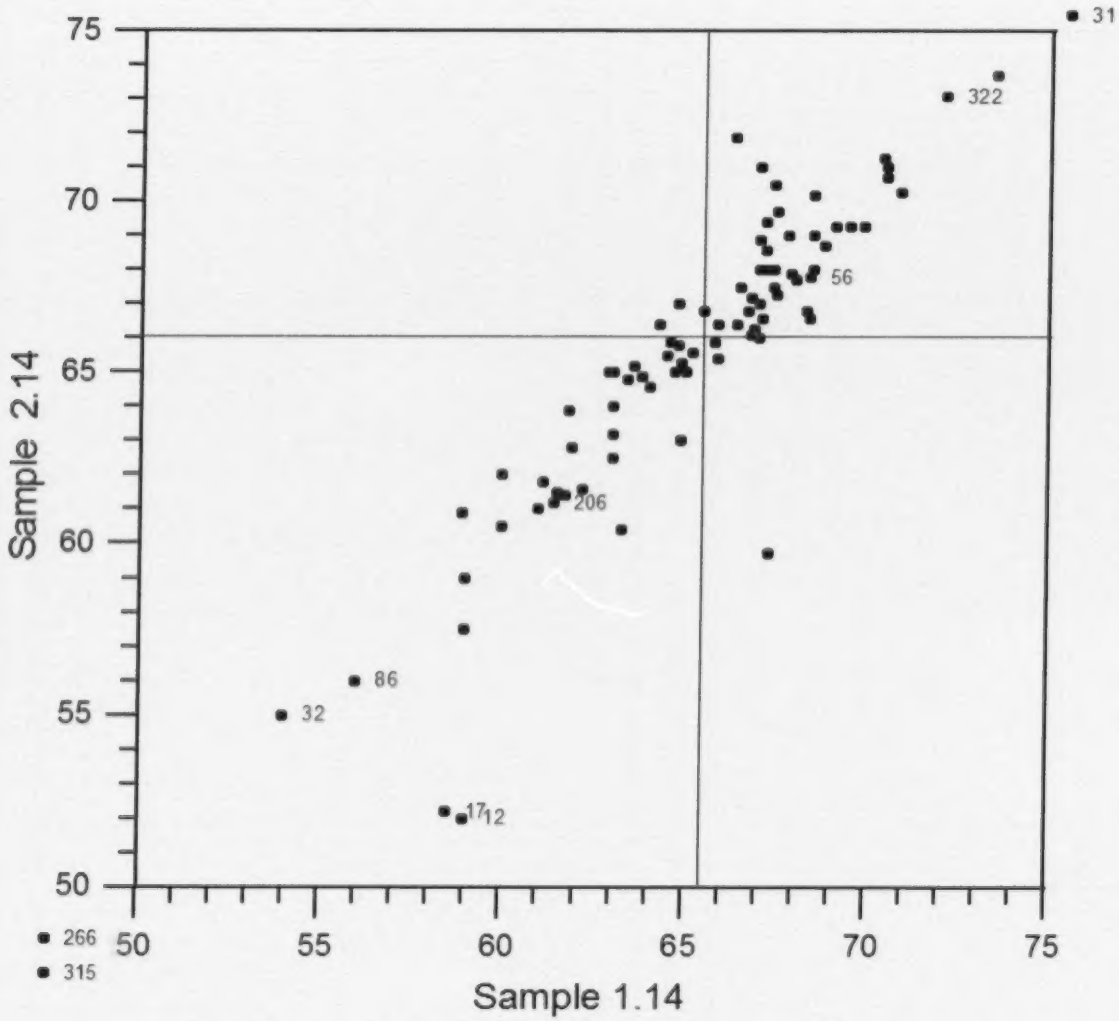
Test 44: Percent Passing the 5 μm Sieve (Soil)

	Mat 1	Mat 2
Mean	76.159	76.946
Median	76.250	76.450
Std Dev	3.026	2.980

n = 78

Labs Eliminated: 12; 17; 32; 52; 56; 63; 206; 266; 315; 322

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



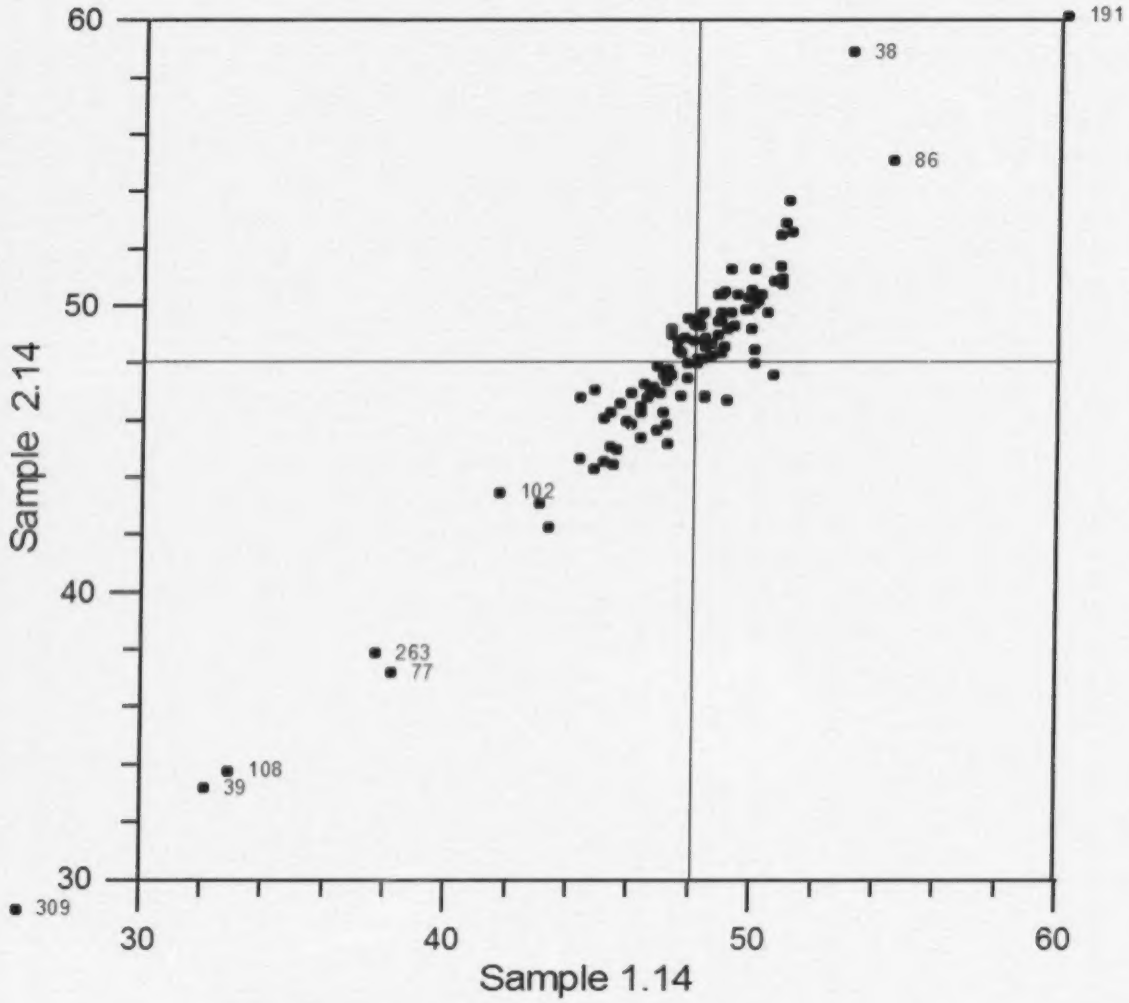
Test 45: Percent Passing the 2 µm Sieve (Soil)

	Mat 1	Mat 2
Mean	65.525	66.153
Median	66.200	65.600
Std Dev	3.160	3.256

n = 78

Labs Eliminated: 12; 17; 31; 32; 56; 86; 206; 266; 315; 322

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



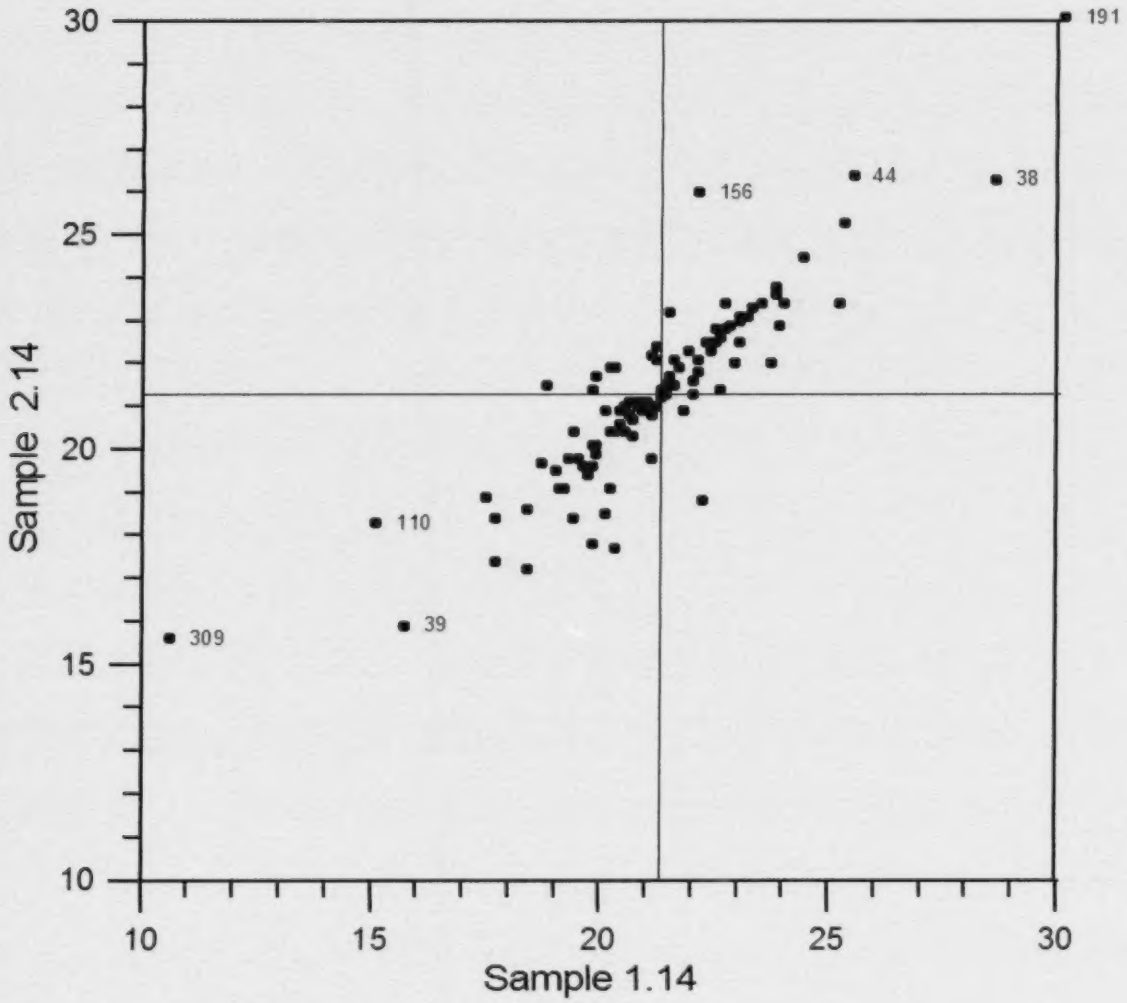
Test 46: Liquid Limit, %

	Mat 1	Mat 2
Mean	48.075	48.317
Median	47.100	48.000
Std Dev	1.933	2.217

n = 99

Labs Eliminated: 38; 39; 77; 86; 102; 108; 191; 263; 309

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



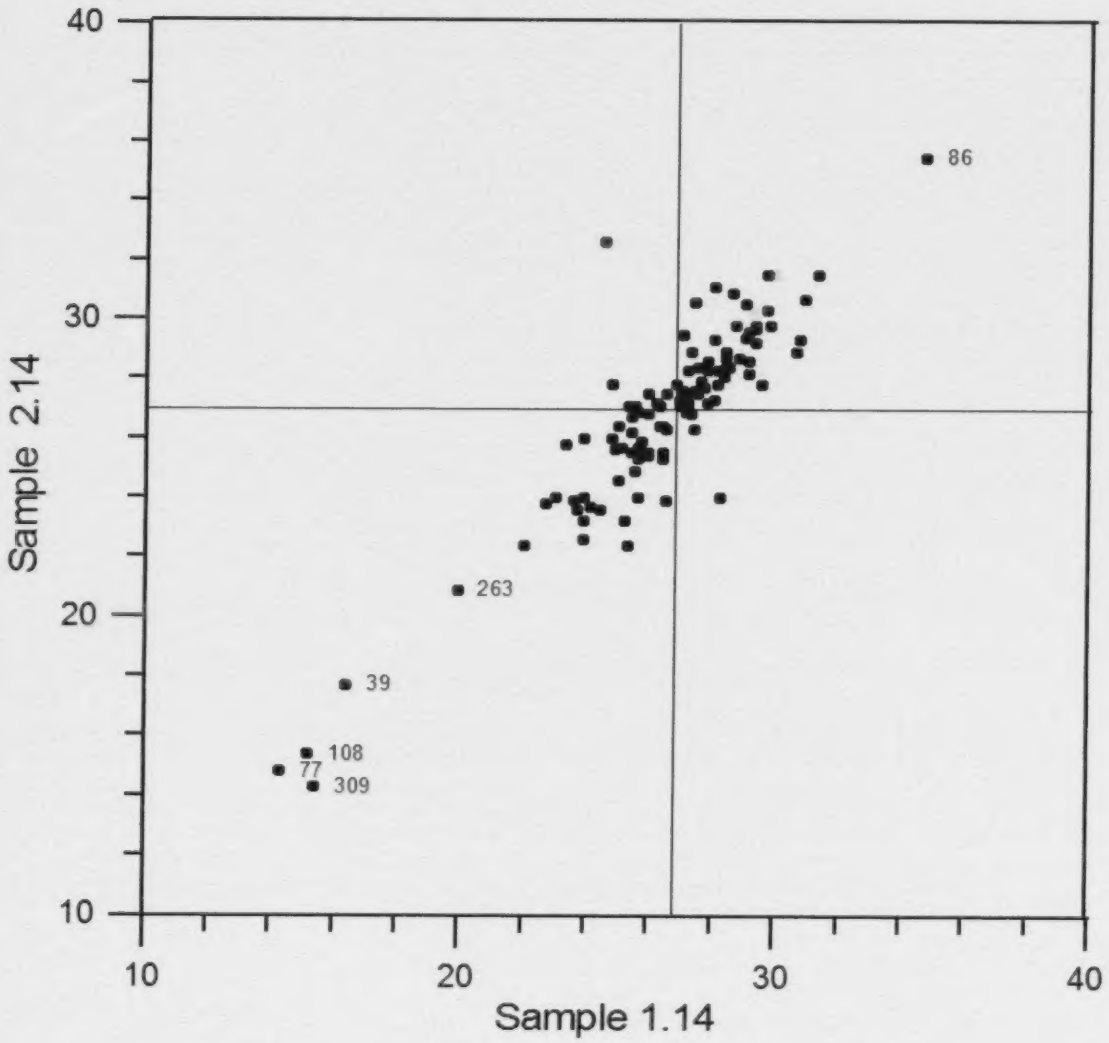
Test 47: Plastic Limit, %

	Mat 1	Mat 2
Mean	21.243	21.169
Median	21.400	21.250
Std Dev	1.658	1.623

n = 101

Labs Eliminated: 38; 39; 44; 110; 156; 191; 309

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



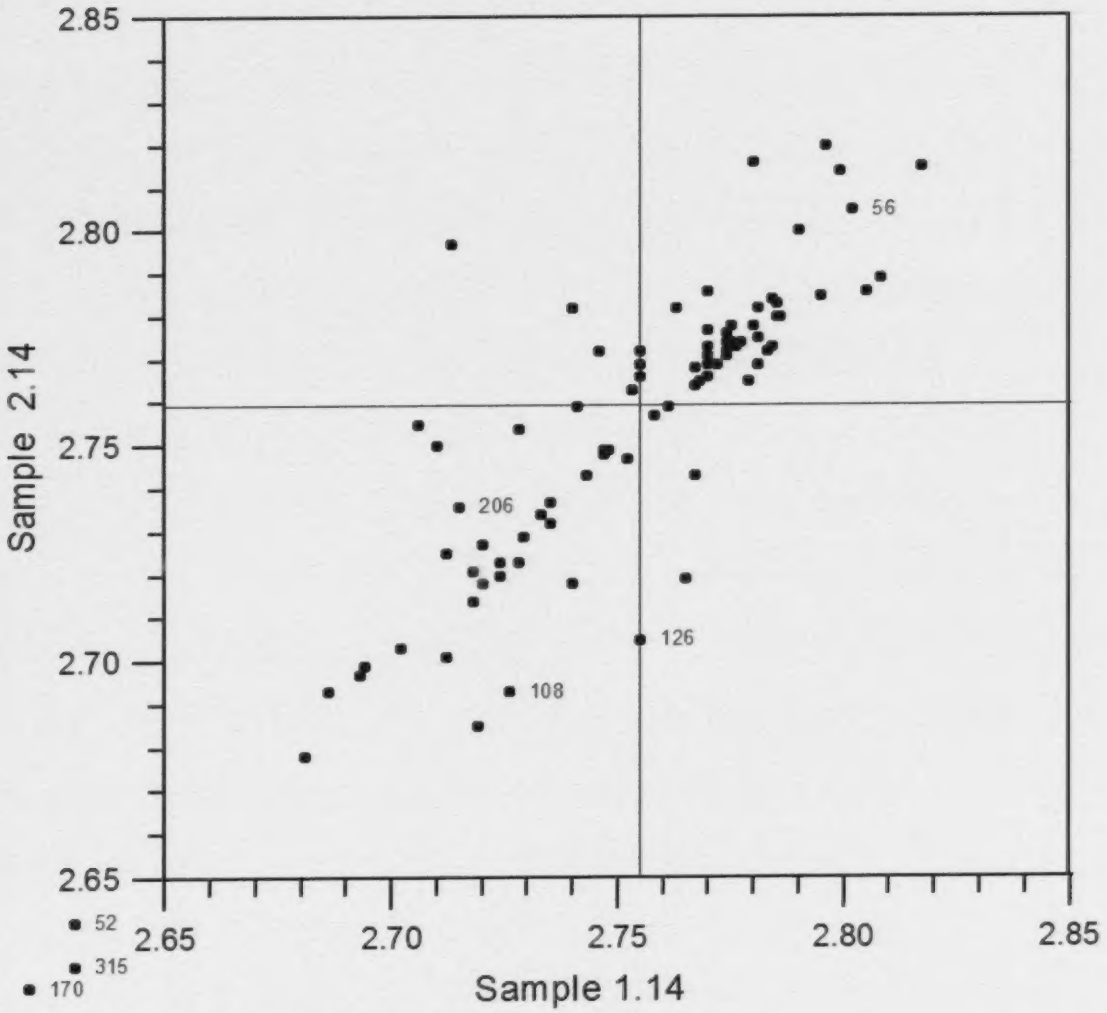
Test 48: Plasticity Index, %

	Mat 1	Mat 2
Mean	26.767	27.028
Median	26.650	27.500
Std Dev	1.954	2.299

n = 102

Labs Eliminated: 39; 77; 86; 108; 263; 309

2014 MTO AGGREGATE AND SOIL PROFICIENCY SAMPLE TESTING PROGRAM



Test 49: Specific Gravity of Soil

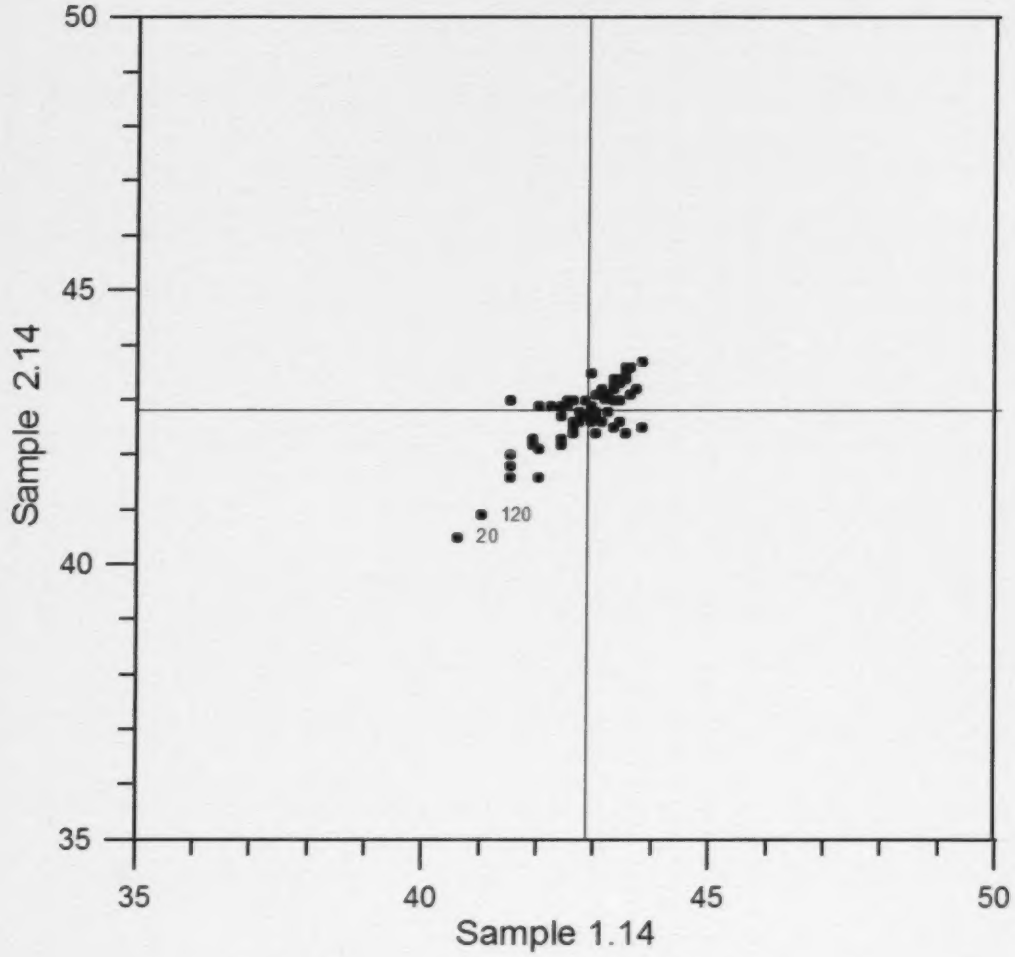
	Mat 1	Mat 2
Mean	2.755	2.758
Median	2.749	2.749
Std Dev	0.030	0.031

n = 82

Labs Eliminated: 52; 56; 108; 126; 170; 206; 315

Appendix D2: Scatter Diagrams

2014 MTO SUPERPAVE
CONSENSUS PROPERTY TESTING PROGRAM



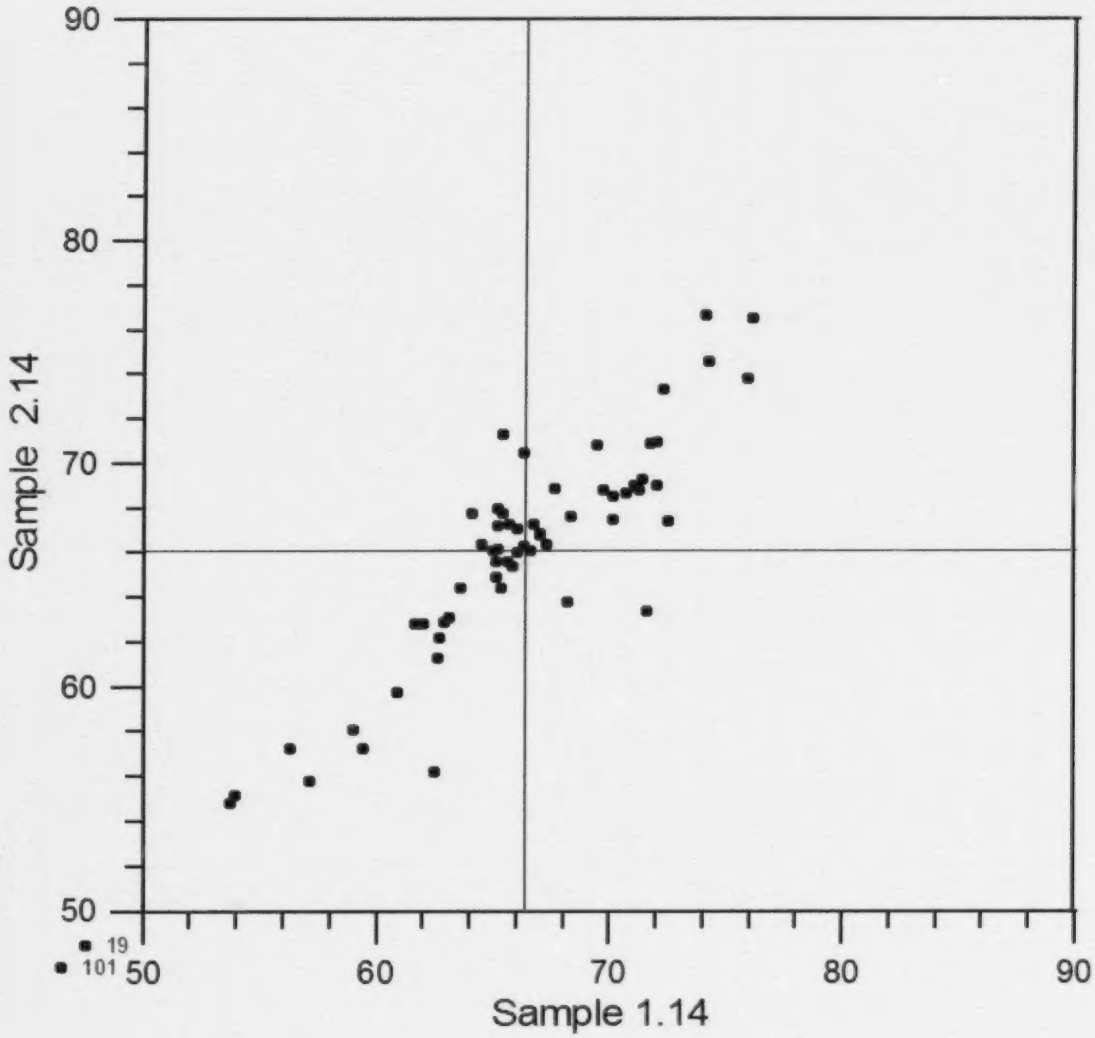
Test 95: Uncompacted Void Content of Fine Aggregate

	Mat 1	Mat 2
Mean	42.852	42.807
Median	42.650	42.650
Std Dev	0.604	0.484

n = 62

Labs Eliminated: 20; 120

2014 MTO SUPERPAVE
CONSENSUS PROPERTY TESTING PROGRAM



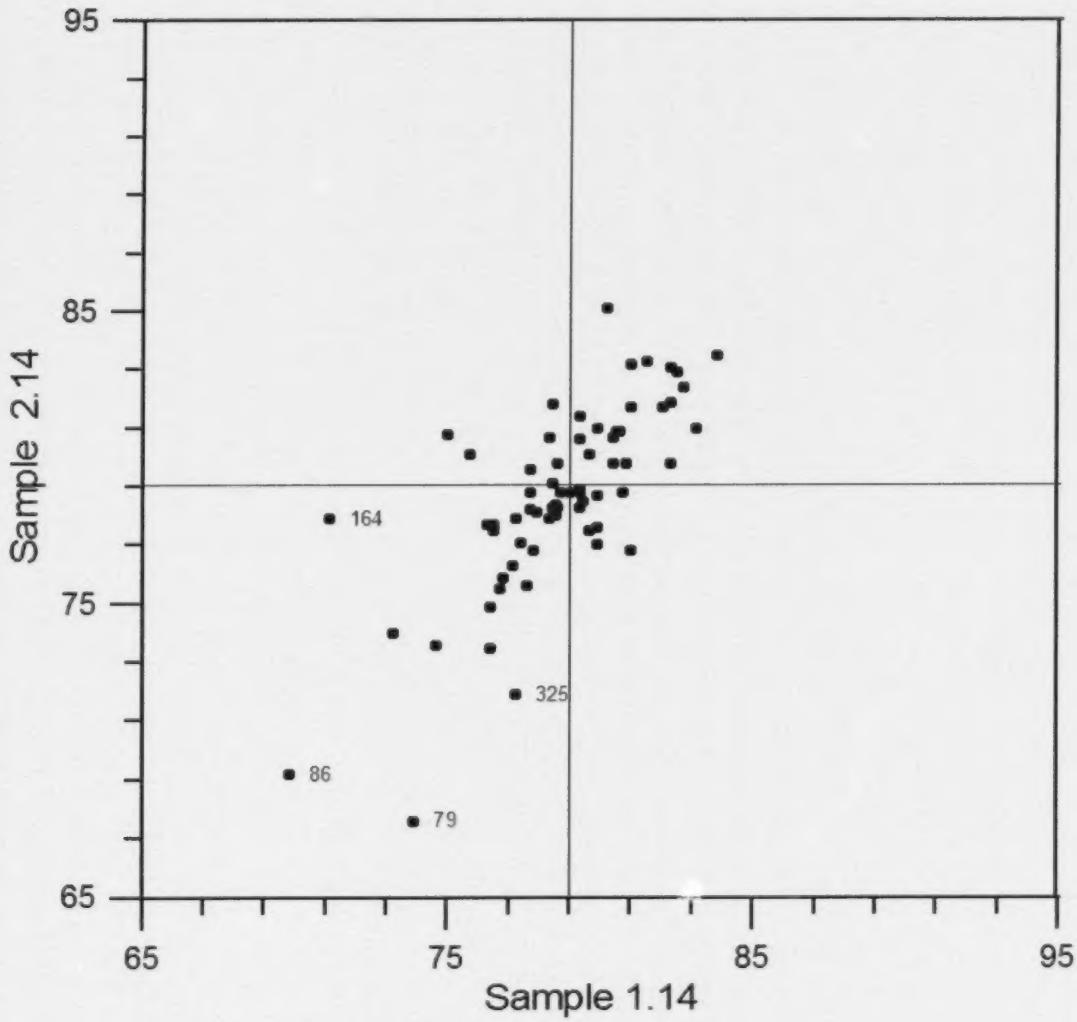
Test 96: Sand Equivalent Value of Fine Aggregate

	Mat 1	Mat 2
Mean	66.325	66.097
Median	64.900	65.750
Std Dev	4.947	4.935

n = 59

Labs Eliminated: 19; 101

2014 MTO SUPERPAVE
CONSENSUS PROPERTY TESTING PROGRAM



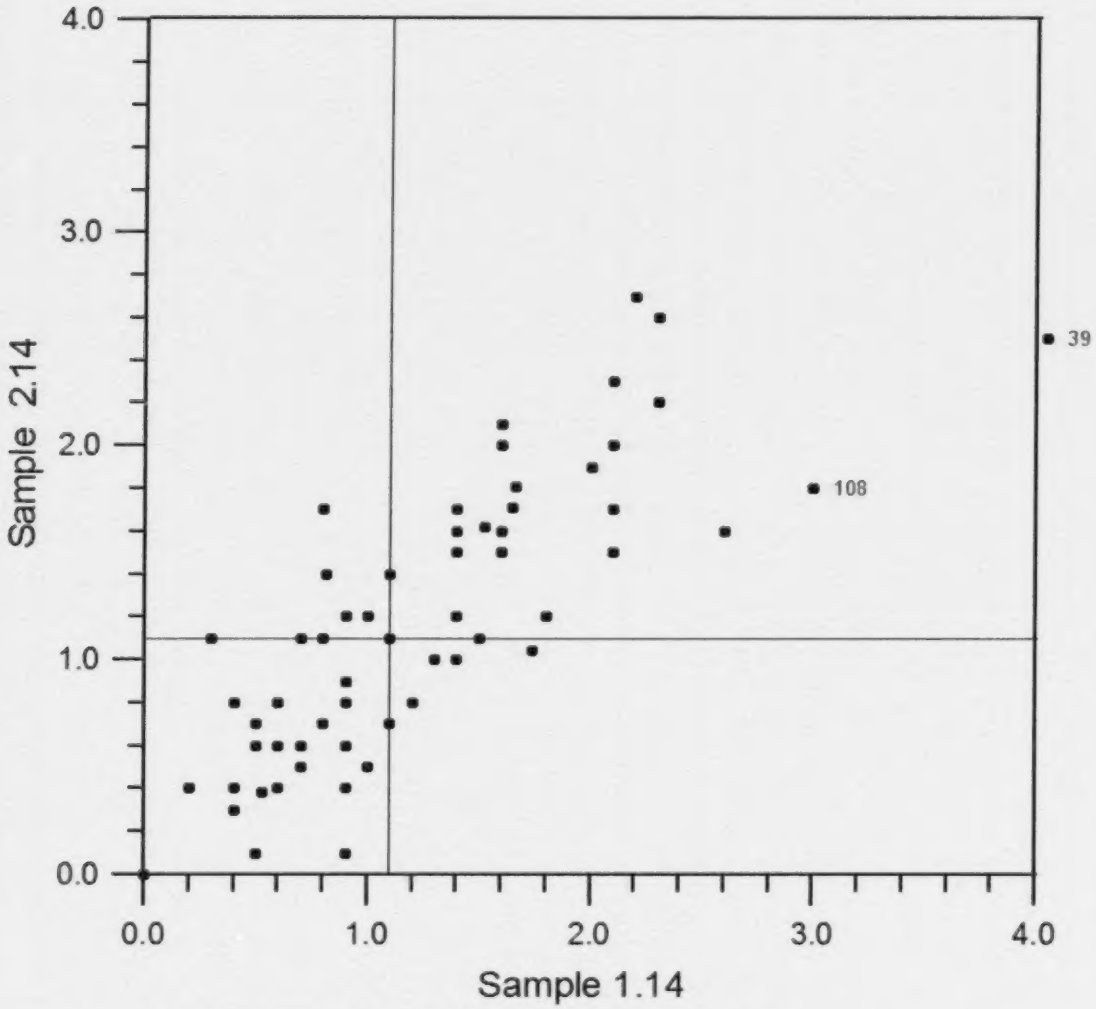
Test 97: Percent Fractured Particles

	Mat 1	Mat 2
Mean	78.997	79.177
Median	78.500	79.300
Std Dev	2.268	2.491

n = 64

Labs Eliminated: 79; 86; 164; 325

2014 MTO SUPERPAVE
CONSENSUS PROPERTY TESTING PROGRAM



Test 99: Percent Flat and Elongated Particles

	Mat 1	Mat 2
Mean	1.120	1.126
Median	1.300	1.350
Std Dev	0.610	0.652

n = 66

Labs Eliminated: 39, 108

Appendix E1: Petrographic Results of Coarse Aggregate

Laboratory Number		1	1	13	13	14	14	15	15	27	27
Sample Number	Type	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST	1.12ST	2.14ST
Carbonate (hard; silty, hard)	1	18.7	20.2	52.3	70.5	65.7	71.1	16.4	14.5	71.5	69.8
Carbonate (surf. Weath.; silty, surf. Weath.; med. Hard; silty, med. Hard)	20	48.8	51.0	22.0	9.4	4.2	3.5	58.7	60.4	5.5	2.2
Carbonate (sandy, hard or medium hard)	2					0.1				1.1	0.5
Carbonate (slightly cherty: <5%)	21	2.0				2.3	1.3			3.7	2.1
Marble (hard or medium hard)	23										
Conglomerate-Sandstone-Arkose (hard)	3						0.4		0.3		
Conglomerate-Sandstone-Arkose (medium hard)	22										
Greywacke - Argillite (hard or medium hard)	6										
Gneiss - Amphibolite - Schist (hard)	4	12.0	12.5	3.6	0.3	18.3	15.3	12.3	15.9	11.5	18.5
Quartzite	5	0.2	0.3		5.3					0.2	
Granite - Diorite - Gabbro (hard)	8	9.5	7.7	13.8	12.0	6.9	4.6	6.9	3.6	3.6	4.3
Volcanic (hard or medium hard)	7					0.6					
Trap (≤20% sulphide)	9										
Quartz (vein or pegmatitic)	10			4.3							
Sibley Group	80										
Total Good Aggregate (%)		**91.2**	**91.7**	**95.9**	**97.8**	**98.1**	**96.2**	**94.3**	**94.7**	**97.1**	**97.4**
Carbonate (soft; silty, soft; slightly shaley)	35	1.7	1.9	3.1	1.4	0.7	1.4	3.6	2.5	1.0	1.0
Carbonate (soft, pitted)	41									0.4	
Carbonate (deeply weathered; silty, deeply weathered)	42	3.3	3.1							0.2	
Carbonate (sandy, soft)	40									0.2	0.5
Chert-Cherty Carbonate (<20% leached chert)	26			0.3		0.1	1.1				0.4
Conglomerate-Sandstone-Arkose (brittle)	30										0.1
Encrustation	52	1.0	0.7								
Gneiss - Amphibolite - Schist (brittle)	25	2.1	1.7	0.5	0.4			1.5	1.1	0.4	0.2
Granite - Diorite - Gabbro (brittle)	27				0.4	0.3	0.3	0.1	0.2		
Volcanic (soft)	28										
Total Fair Aggregate (%)		**8.1**	**7.4**	**4.0**	**2.2**	**1.1**	**2.8**	**5.2**	**3.8**	**2.2**	**2.2**
Carbonate (shaley; clayey; silty, clayey)	43					0.5	0.4	0.4	1.2	0.7	0.2
Carbonate (ochreous; sandy, ochreous)	44										
Chert-Cherty Carbonate (>20% leached chert)	45					0.3	0.6				0.2
Conglomerate-Sandstone-Arkose (friable)	46										
Siltstone	56										
Cementation (partial)	53	0.7	0.9	0.1	0.0						
Cementation (total)	54										
Gneiss-Amphibolite (friable)	50							0.1	0.3		
Granite-Diorite-Gabbro (friable)	51										
Total poor Aggregate (%)		**0.7**	**0.9**	**0.1**		**0.8**	**1.0**	**0.5**	**1.5**	**0.7**	**0.4**
Clay	62										
Volcanic-Gness-Schist (decomposed)	63										
Carbonate (sandy, friable)											
Total Deleterious Aggregate (%)											
Reported total mass examined (g)		**1499.5**	**1503.3**	**1493.2**	**1504.1**	**NR**	**NR**	**1511.2**	**1520.6**	**1642.4**	**1663.7**
Reported PN		**119.7**	**119.5**	**109**	**104**	**106.2**	**110.6**	**113**	**115**	**107.9**	**106.4**

Laboratory Number		30	30	31	31	35	35	38	38	39	39
Sample Number	Type	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST
Carbonate (hard; silty, hard)	1	34.9	53.0	32.3	32.9	64.6	63.3			17.2	41.8
Carbonate (surf. Weath.; silty, surf. Weath.; med. Hard; silty, med. Hard)	20	5.0	6.2	39.4	40.7	10.3	9.0			58.4	33.4
Carbonate (sandy, hard or medium hard)	2	27.6	19.4								
Carbonate (slightly cherty: <5%)	21							49.1	55.7		
Marble (hard or medium hard)	23										
Conglomerate-Sandstone-Arkose (hard)	3		1.6							0.3	0.4
Conglomerate-Sandstone-Arkose (medium hard)	22										
Greywacke - Argillite (hard or medium hard)	6										
Gneiss - Amphibolite - Schist (hard)	4	14.1	9.7	20.7	21.3	21.7	24.9	15.4	14.8	8.2	7.6
Quartzite	5										
Granite - Diorite - Gabbro (hard)	8	5.7	5.4							13.1	13.8
Volcanic (hard or medium hard)	7										
Trap (≤20% sulphide)	9										
Quartz (vein or pegmatitic)	10										
Sibley Group	80										
Total Good Aggregate (%)		**87.3**	**95.3**	**92.4**	**94.9**	**96.6**	**97.1**	**64.5**	**70.5**	**97.2**	**97.0**
Carbonate (soft; silty, soft; slightly shaley)	35		1.4	4.0	2.8	2.4	1.9				
Carbonate (soft, pitted)	41									0.1	0.1
Carbonate (deeply weathered; silty, deeply weathered)	42										
Carbonate (sandy, soft)	40	6.1									
Chert-Cherty Carbonate (<20% leached chert)	26							28.7	21.3		0.3
Conglomerate-Sandstone-Arkose (brittle)	30		1.7							0.3	
Encrustation	52			0.2							
Gneiss - Amphibolite - Schist (brittle)	25	3.1	1.1	3.3	2.3	0.3	0.5	4.1	4.2		
Granite - Diorite - Gabbro (brittle)	27	1.0								1.1	1.2
Volcanic (soft)	28										
Total Fair Aggregate (%)		**10.2**	**4.2**	**7.5**	**5.1**	**2.7**	**2.3**	**32.8**	**25.5**	**1.6**	**1.7**
Carbonate (shaley; clayey; silty, clayey)	43			0.1		0.4	0.3				
Carbonate (ochreous; sandy, ochreous)	44	2.5									
Chert-Cherty Carbonate (>20% leached chert)	45							2.7	4.0	0.8	0.8
Conglomerate-Sandstone-Arkose (friable)	46		0.5								
Siltstone	56										
Cementation (partial)	53					0.3	0.2				
Cementation (total)	54										0.6
Gneiss-Amphibolite (friable)	50									0.5	
Granite-Diorite-Gabbro (friable)	51										
Total poor Aggregate (%)		**2.5**	**0.5**	**0.1**		**0.7**	**0.5**	**2.7**	**4.0**	**1.3**	**1.3**
Clay	62										
Volcanic-Gness-Schist (decomposed)	63										
Carbonate (sandy, friable)											
Total Deleterious Aggregate (%)											
Reported total mass examined (g)		**1565.3**	**1550.2**	**1498.2**	**1503.0**	**1501.5**	**1500.1**	**1501.5**	**1501.7**	**1451.5**	**1475.5**
Reported PN		**133**	**111**	**116**	**110**	**109**	**107**	**179**	**171**	**110**	**110**

Laboratory Number		40	40	47	47	61	61	76	76	77	77
Sample Number	Type	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST
Carbonate (hard; silty, hard)	1	56.7	68.8	51.1	56.7	68.5	62.7	55.1	55.6	47.1	46.2
Carbonate (surf. Weath.; silty, surf. Weath.; med. Hard; silty, med. Hard)	20	21.4	10.6	22.0	15.8	4.5	8.3	15.7	14.2	29.3	30.9
Carbonate (sandy, hard or medium hard)	2		0.1	0.3							
Carbonate (slightly cherty: <5%)	21	0.3		1.1	2.5			0.8	2.2		
Marble (hard or medium hard)	23					5.4	7.3				
Conglomerate-Sandstone-Arkose (hard)	3		0.7			0.8					
Conglomerate-Sandstone-Arkose (medium hard)	22										
Greywacke - Argillite (hard or medium hard)	6										
Gneiss - Amphibolite - Schist (hard)	4	16.2	9.7	14.4	14.1			1.5	1.2		
Quartzite	5										
Granite - Diorite - Gabbro (hard)	8	2.3	7.0	4.5	6.2	17.1	17.8	17.0	16.8	17.2	17.0
Volcanic (hard or medium hard)	7										
Trap (≤20% sulphide)	9					1.8	1.1				
Quartz (vein or pegmatitic)	10				0.1					0.1	0.1
Sibley Group	80										
Total Good Aggregate (%)		**96.9**	**96.9**	**93.4**	**95.3**	**98.1**	**97.2**	**90.1**	**90.0**	**93.6**	**94.2**
Carbonate (soft; silty, soft; slightly shaley)	35			1.3	0.5			1.1	3.2	2.3	2.0
Carbonate (soft, pitted)	41		0.4	0.5	0.1	0.1	0.3				
Carbonate (deeply weathered; silty, deeply weathered)	42	2.5	0.9	3.3	2.1			4.1	3.2		
Carbonate (sandy, soft)	40									1.1	0.9
Chert-Cherty Carbonate (<20% leached chert)	26							0.2		3.6	2.9
Conglomerate-Sandstone-Arkose (brittle)	30										
Encrustation	52										
Gneiss - Amphibolite - Schist (brittle)	25		0.5	0.4	0.4			0.7	0.2		
Granite - Diorite - Gabbro (brittle)	27			0.1				3.0	2.5		
Volcanic (soft)	28					1.8	2.5				
Total Fair Aggregate (%)		**2.5**	**1.7**	**5.6**	**3.1**	**1.9**	**2.8**	**9.1**	**9.1**	**7.0**	**5.8**
Carbonate (shaley; clayey; silty, clayey)	43			0.8	0.9			0.5	0.6		
Carbonate (ochreous; sandy, ochreous)	44										
Chert-Cherty Carbonate (>20% leached chert)	45										
Conglomerate-Sandstone-Arkose (friable)	46										
Siltstone	56										
Cementation (partial)	53				0.3			0.3			
Cementation (total)	54		1.4		0.3						
Gneiss-Amphibolite (friable)	50	0.6		0.2							
Granite-Diorite-Gabbro (friable)	51								0.2		
Total poor Aggregate (%)		**0.6**	**1.4**	**1.0**	**1.5**			**0.8**	**0.8**	**0.0**	
Clay	62	0.1	0.3								
Volcanic-Gness-Schist (decomposed)	63										
Carbonate (sandy, friable)											
Total Deleterious Aggregate (%)		**0.1**	**0.3**								
Reported total mass examined (g)		**1493.0**	**1495.0**	**1490.0**	**1493.0**	**1570.8**	**1593.2**	**1516.3**	**1544.6**	**1501.2**	**1504.6**
Reported PN		**108.6**	**113.2**	**116.2**	**114.0**	**104**	**106**	**122**	**122**	**115.0**	**112.0**

Laboratory Number		79	79	80	80	81	81	86	86	88	88
Sample Number	Type	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST
Carbonate (hard; silty, hard)	1	34.3	32.9	76.2	74.0	55.8	53.7	43.8	23.9	60.4	60.4
Carbonate (surf. Weath.; silty, surf. Weath.; med. Hard; silty, med. Hard)	20	32.1	30.8			22.5	20.3	24.2	37.2	11.8	10.4
Carbonate (sandy, hard or medium hard)	2	0.1								0.2	0.8
Carbonate (slightly cherty: <5%)	21	2.0	3.1								0.5
Marble (hard or medium hard)	23										
Conglomerate-Sandstone-Arkose (hard)	3	0.9									0.4
Conglomerate-Sandstone-Arkose (medium hard)	22										
Greywacke - Argillite (hard or medium hard)	6					0.1					
Gneiss - Amphibolite - Schist (hard)	4	11.4	13.0	9.3	5.9	7.3	13.6	3.1	2.4	7.9	4.9
Quartzite	5			0.7	0.5				0.3	0.5	
Granite - Diorite - Gabbro (hard)	8	4.8	4.4	11.8	16.5	9.7	7.4	7.7	12.6	14.9	18.5
Volcanic (hard or medium hard)	7				1.4						
Trap (≤20% sulphide)	9				0.5						
Quartz (vein or pegmatitic)	10					0.2					
Sibley Group	80							6.3	5.3		
Total Good Aggregate (%)		**85.6**	**84.2**	**98.0**	**98.8**	**95.6**	**94.9**	**84.6**	**81.7**	**95.8**	**96.0**
Carbonate (soft; silty, soft; slightly shaley)	35	4.2	5.6	1.4	0.9			6.6	7.1	1.2	2.2
Carbonate (soft, pitted)	41		0.3								
Carbonate (deeply weathered; silty, deeply weathered)	42	0.9	1.0			1.9	3.1				
Carbonate (sandy, soft)	40	0.0	0.3							0.5	0.4
Chert-Cherty Carbonate (<20% leached chert)	26	2.8	2.7		0.3	0.1	0.2			0.4	0.1
Conglomerate-Sandstone-Arkose (brittle)	30										
Encrustation	52					1.1				0.2	
Gneiss - Amphibolite - Schist (brittle)	25	6.0	2.3			0.9				0.7	0.3
Granite - Diorite - Gabbro (brittle)	27									0.6	0.4
Volcanic (soft)	28										
Total Fair Aggregate (%)		**13.8**	**12.1**	**1.4**	**1.2**	**4.0**	**3.3**	**6.6**	**7.1**	**3.6**	**3.4**
Carbonate (shaley; clayey; silty, clayey)	43	0.2	3.2	0.2		0.4	1.8		1.5		0.1
Carbonate (ochreous; sandy, ochreous)	44	0.1	0.3								0.1
Chert-Cherty Carbonate (>20% leached chert)	45							8.4	9.3		
Conglomerate-Sandstone-Arkose (friable)	46										
Siltstone	56										
Cementation (partial)	53	0.2		0.4					0.5	0.6	0.3
Cementation (total)	54										
Gneiss-Amphibolite (friable)	50	0.1	0.3								
Granite-Diorite-Gabbro (friable)	51										
Total poor Aggregate (%)		**0.6**	**3.7**	**0.6**		**0.4**	**1.8**	**8.4**	**11.2**	**0.6**	**0.6**
Clay	62										
Volcanic-Gness-Schist (decomposed)	63										
Carbonate (sandy, friable)											
Total Deleterious Aggregate (%)											
Reported total mass examined (g)		**1498.4**	**1499.7**	**1503.1**	**1503.0**	**1566.9**	**1546.8**	**1493.2**	**1503.7**	**1543.9**	**1571.8**
Reported PN		**131**	**143**	**106**	**102**	**110.0**	**115.6**	**154.4**	**170.1**	**110**	**110**

Laboratory Number		96	96	101	101	102	102	114	114	133	133
Sample Number	Type	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST
Carbonate (hard; silty, hard)	1	38.6	31.8	71.9	72.0	39.0	40.3	69.8	71.9	24.7	19.0
Carbonate (surf. Weath.; silty, surf. Weath.; med. Hard; silty, med. Hard)	20	31.6	36.4	4.4	4.0	36.1	36.5			48.1	55.8
Carbonate (sandy, hard or medium hard)	2		1.4								
Carbonate (slightly cherty: <5%)	21	1.6	2.0		0.7						
Marble (hard or medium hard)	23										
Conglomerate-Sandstone-Arkose (hard)	3	0.3	0.5	0.6	0.2	0.8	1.7	1.7	1.0		
Conglomerate-Sandstone-Arkose (medium hard)	22										
Greywacke - Argillite (hard or medium hard)	6										
Gneiss - Amphibolite - Schist (hard)	4	13.5	12.5	8.6	8.4	2.9	2.5	17.1	17.7	11.1	9.9
Quartzite	5										
Granite - Diorite - Gabbro (hard)	8	8.4	9.3	10.8	11.1	16.3	14.1	4.3		7.4	6.6
Volcanic (hard or medium hard)	7	1.1	0.3								
Trap (≤20% sulphide)	9				0.3	1.0					
Quartz (vein or pegmatitic)	10			0.3	0.2			1.8	0.8		
Sibley Group	80										
Total Good Aggregate (%)		**95.1**	**94.2**	**96.6**	**96.9**	**96.1**	**95.1**	**94.7**	**91.3**	**91.3**	**91.3**
Carbonate (soft; silty, soft; slightly shaley)	35	3.0	4.2	0.8	0.9	0.9	0.7	1.8	2.0	6.1	6.7
Carbonate (soft, pitted)	41					0.3	0.1				
Carbonate (deeply weathered; silty, deeply weathered)	42			1.2	0.3						
Carbonate (sandy, soft)	40	0.6	0.2			0.6	1.0				
Chert-Cherty Carbonate (<20% leached chert)	26		0.2	0.2					0.6	1.1	
Conglomerate-Sandstone-Arkose (brittle)	30										
Encrustation	52									0.4	0.5
Gneiss - Amphibolite - Schist (brittle)	25	0.2	0.6	0.7	0.7	1.2	1.4	0.2	2.0	0.4	0.7
Granite - Diorite - Gabbro (brittle)	27	0.3	0.4			0.2	0.4			0.1	0.1
Volcanic (soft)	28										
Total Fair Aggregate (%)		**4.0**	**5.7**	**2.9**	**1.9**	**3.3**	**3.6**	**2.0**	**4.5**	**8.1**	**8.0**
Carbonate (shaley; clayey; silty, clayey)	43	0.2		0.3	1.2	0.5	1.3	1.9	4.2	0.1	
Carbonate (ochreous; sandy, ochreous)	44	0.6	0.1								0.1
Chert-Cherty Carbonate (>20% leached chert)	45										
Conglomerate-Sandstone-Arkose (friable)	46										
Siltstone	56										
Cementation (partial)	53			0.1				0.9		0.5	0.6
Cementation (total)	54										
Gneiss-Amphibolite (friable)	50			0.1				0.4			
Granite-Diorite-Gabbro (friable)	51										
Total poor Aggregate (%)		**0.8**	**0.1**	**0.5**	**1.2**	**0.5**	**1.3**	**3.3**	**4.2**	**0.6**	**0.7**
Clay	62										
Volcanic-Gness-Schist (decomposed)	63										
Carbonate (sandy, friable)		0.1									
Total Deleterious Aggregate (%)		**0.1**									
Reported total mass examined (g)		**1552.7**	**1539.5**	**1506.3**	**1510.0**	**1545.4**	**1545.4**	**1509.8**	**1474.1**	**1504.7**	**1501.1**
Reported PN		**113**	**112**	**108**	**110**	**109.4**	**114**	**120**	**130**	**119**	**120**

Laboratory Number		152	152	166	166	183	183	188	188	206	206
Sample Number	Type	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST	1.14ST	2.14ST
Carbonate (hard; silty, hard)	1	57.2	53.6	26.4	20.9	5.3	12.8	53.6	60.4	65.0	61.0
Carbonate (surf. Weath.; silty, surf. Weath.; med. Hard; silty, med. Hard)	20	12.1	11.7	44.5	52.1	65.8	61.5	14.4	9.9		
Carbonate (sandy, hard or medium hard)	2	1.4	2.3					2.0	0.2		2.5
Carbonate (slightly cherty: <5%)	21		1.8					1.1	2.9		
Marble (hard or medium hard)	23										
Conglomerate-Sandstone-Arkose (hard)	3					0.2	0.5	0.2	0.3	1.3	
Conglomerate-Sandstone-Arkose (medium hard)	22									0.2	
Greywacke - Argillite (hard or medium hard)	6									0.0	
Gneiss - Amphibolite - Schist (hard)	4	18.2	21.5	12.3	9.0	3.9	1.7	15.1	15.7	6.0	11.5
Quartzite	5								0.3	5.4	5.4
Granite - Diorite - Gabbro (hard)	8	5.8	3.6	10.9	10.3	22.2	17.1	6.0	5.7	17.0	14.4
Volcanic (hard or medium hard)	7										
Trap (≤20% sulphide)	9						1.5				
Quartz (vein or pegmatitic)	10							0.4	0.6		
Sibley Group	80										
Total Good Aggregate (%)		**94.6**	**94.6**	**94.1**	**92.3**	**97.31**	**94.93**	**92.8**	**96.0**	**94.9**	**94.8**
Carbonate (soft; silty, soft; slightly shaley)	35	2.0	3.8	2.7	3.1	2.3	4.5	2.9	1.1	1.2	1.4
Carbonate (soft, pitted)	41										0.4
Carbonate (deeply weathered; silty, deeply weathered)	42								0.5		
Carbonate (sandy, soft)	40							0.3			
Chert-Cherty Carbonate (<20% leached chert)	26			0.1	0.1			1.2	1.0		
Conglomerate-Sandstone-Arkose (brittle)	30										
Encrustation	52	0.1	0.3	0.3	0.6					0.7	1.0
Gneiss - Amphibolite - Schist (brittle)	25	0.3	0.7	0.7	1.1			0.8	0.5	0.8	1.4
Granite - Diorite - Gabbro (brittle)	27			0.1	0.3			0.3	0.1	0.7	0.5
Volcanic (soft)	28										
Total Fair Aggregate (%)		**2.5**	**4.8**	**3.9**	**5.2**	**2.33**	**4.45**	**5.5**	**3.2**	**3.4**	**4.7**
Carbonate (shaley; clayey; silty, clayey)	43	0.8	0.1	1.5	1.6		0.4	0.1		1.2	
Carbonate (ochreous; sandy, ochreous)	44	0.8						0.1			
Chert-Cherty Carbonate (>20% leached chert)	45			0.1	0.6			0.1			
Conglomerate-Sandstone-Arkose (friable)	46										
Siltstone	56									0.5	0.2
Cementation (partial)	53	1.2	0.5	0.4	0.3			0.1	0.8		
Cementation (total)	54										
Gneiss-Amphibolite (friable)	50							1.0			
Granite-Diorite-Gabbro (friable)	51							0.2			0.3
Total poor Aggregate (%)		**2.9**	**0.6**	**2.0**	**2.5**		**0.39**	**1.6**	**0.8**	**1.7**	**0.5**
Clay	62					0.4	0.2				
Volcanic-Gness-Schist (decomposed)	63							0.1			
Carbonate (sandy, friable)											
Total Deleterious Aggregate (%)						**0.4**	**0.23**	**0.1**			
Reported total mass examined (g)		**1528.6**	**1541.7**	**1529.6**	**1526.1**	**1512.3**	**1501.1**	**1548.2**	**1558.3**	**1535.7**	**1508.0**
Reported PN		**119**	**113**	**118**	**123**	**108**	**113**	**120**	**110**	**115**	**112**

Appendix E2: Petrographic Results of Fine Aggregate

Laboratory Number	15	15	27	27	35	35	47	47	79	79	80	80
Sample Number	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**
Silicate (4.75-2.36 mm)	29.5	32.0	15.0	24.0	24.0	23.5	24.0	27.0	25.8	23.7	20.5	24.4
Silicate (2.36-1.18 mm)	34.5	34.0	30.0	34.0	35.0	33.5	33.5	33.0	29.7	35.2	30.9	33.3
Silicate (1.18-0.600 mm)	43.5	45.0	50.0	43.0	45.0	48.5	54.5	58.0	48.8	47.9	50.0	52.8
Silicate (0.600-0.300 mm)	64.0	60.5	69.0	68.0	65.0	67.5	67.5	69.5	64.7	65.1	78.6	69.5
Silicate (0.300-0.150 mm)	76.0	76.0	77.5	80.0	81.5	80.0	77.5	71.0	66.6	72.7	89.3	86.7
Silicate (0.150-0.075 mm)	78.0	76.5	82.0	85.5	86.0	85.0	71.5	71.0	76.6	68.9	83.9	89.9
Silicate (wt. avg. %)	**49.4**	**49.9**	**56.3**	**49.5**	**50.7**	**52.0**	**53.0**	**52.9**	**49.8**	**48.6**	**52.6**	**53.2**
Carbonate (4.75-2.36 mm)	70.0	67.0	79.0	68.5	74.5	75.0	75.5	72.5	72.7	74.9	77.0	74.1
Carbonate (2.36-1.18 mm)	65.5	66.0	63.5	60.0	64.0	65.5	66.0	66.5	69.5	64.3	65.0	65.2
Carbonate (1.18-0.600 mm)	55.5	54.5	42.0	46.5	55.0	51.5	45.0	41.5	50.7	50.7	49.1	44.9
Carbonate (0.600-0.300 mm)	32.5	36.5	26.0	27.5	34.5	32.0	29.5	29.0	33.2	34.1	20.5	30.0
Carbonate (0.300-0.150 mm)	18.5	19.0	16.0	14.0	16.0	18.0	14.5	21.5	24.4	19.7	6.5	11.9
Carbonate (0.150-0.075 mm)	14.0	16.5	11.0	9.5	11.5	12.5	18.5	21.5	15.8	14.1	10.1	7.5
Carbonate (wt. avg. %)	**48.4**	**48.1**	**37.2**	**43.5**	**48.3**	**47.1**	**44.4**	**45.2**	**47.6**	**48.9**	**44.4**	**44.5**
Shale (4.75-2.36 mm)												
Shale (2.36-1.18 mm)												
Shale (1.18-0.600 mm)				2.0								
Shale (0.600-0.300 mm)				1.0					0.4			
Shale (0.300-0.150 mm)												
Shale (0.150-0.075 mm)									0.2	0.3		
Shale (wt. avg. %)				**0.7**					**0.1**	**0.0**		
Mica (4.75-2.36 mm)									0.5			
Mica (2.36-1.18 mm)										0.5		
Mica (1.18-0.600 mm)	1.0	0.5					0.5	0.5	0.5	0.9		
Mica (0.600-0.300 mm)	3.5	3.0	0.5	2.0	0.5	0.5	3.0	1.5	1.8	0.9	1.0	0.5
Mica (0.300-0.150 mm)	5.5	5.0	2.5	3.5	2.5	2.0	8.0	7.5	9.0	7.6	3.7	1.0
Mica (0.150-0.075 mm)	8.0	7.0	4.0	4.0	2.5	2.5	10.0	7.5	7.4	16.7	6.0	2.6
Mica (wt. avg. %)	**2.1**	**1.8**	**0.8**	**1.1**	**0.6**	**0.5**	**2.4**	**1.7**	**2.2**	**2.2**	**0.9**	**0.3**
Chert (4.75-2.36 mm)			0.5	0.5					0.5	0.5	0.5	
Chert (2.36-1.18 mm)				1.0					0.8		0.5	0.5
Chert (1.18-0.600 mm)			1.5	1.5						0.5		
Chert (0.600-0.300 mm)												
Chert (0.300-0.150 mm)												
Chert (0.150-0.075 mm)												
Chert (wt. avg. %)			**0.4**	**0.7**					**0.2**	**0.2**	**0.2**	**0.1**

Laboratory Number	**15**	**15**	**27**	**27**	**35**	**35**	**47**	**47**	**79**	**79**	**80**	**80**
Sample Number	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**
Cemented Particles (4.75-2.36 mm)	0.5	1.0	2.0		1.5	1.5	0.5	0.5	0.5	0.9		0.5
Cemented Particles (2.36-1.18 mm)			0.5	0.5	1.0	1.0	0.5	0.5			1.8	1.0
Cemented Particles (1.18-0.600 mm)			0.5	1.5								
Cemented Particles (0.600-0.300 mm)												
Cemented Particles (0.300-0.150 mm)			0.5									
Cemented Particles (0.150-0.075 mm)			0.5									
Cemented Particles (wt. avg. %)	**0.1**	**0.2**	**0.5**	**0.4**	**0.4**	**0.4**	**0.2**	**0.2**	**0.1**	**0.2**	**0.3**	**0.3**
Conglomerate, sandstone, quartzite (4.75-2.36 mm)			3.5	7.0							2.0	1.0
Conglomerate, sandstone, quartzite (2.36-1.18 mm)			6.0	4.5							1.8	
Conglomerate, sandstone, quartzite (1.18-0.600 mm)			6.0	5.0							0.9	2.3
Conglomerate, sandstone, quartzite (0.600-0.300 mm)			3.0	0.5								
Conglomerate, sandstone, quartzite (0.300-0.150 mm)			1.5									
Conglomerate, sandstone, quartzite (0.150-0.075 mm)			0.5									
Conglomerate, sandstone, quartzite (wt. avg. %)	**0.0**	**0.0**	**3.9**	**3.5**							**0.9**	**0.7**
Oxide Minerals (4.75-2.36 mm)												
Oxide Minerals (2.36-1.18 mm)												
Oxide Minerals (1.18-0.600 mm)				0.5								
Oxide Minerals (0.600-0.300 mm)			1.5	1.0								
Oxide Minerals (0.300-0.150 mm)			2.0	2.5							0.5	0.5
Oxide Minerals (0.150-0.075 mm)			2.0	1.0								
Oxide Minerals **(wt. avg. %)**			**0.9**	**0.6**							**0.1**	**0.1**
Gradation (% retained)												
(4.75-2.36 mm)	17.1	15.7	7.5	18	16.1	15.5	15.6	16.8	13.4	17.6	20.4	18.6
(2.36-1.18 mm)	20.3	19.5	15.2	19.5	19	18.1	17.9	19	18.9	21.6	18	17.5
(1.18-0.600 mm)	23.2	23.4	27.4	24.1	22.8	22.5	24	24.2	24.9	22.2	22.9	23.4
(0.600-0.300 mm)	23.2	24.2	25.5	23.1	23.5	23.9	24.3	22.9	23.7	22.4	22.9	23.7
(0.300-0.150 mm)	11.2	12	18.6	11.7	11.2	11.3	13.2	12.1	13.4	11	11.7	12.3
(0.150-0.075 mm)	3.4	3.6	6	3.6	3.5	3.4	3.8	3.3	4.2	3.7	3.6	3.8
pass 75 µm	1.6	1.6	0	0	1.5	1.6	1.3	1.6	1.5	1.5	0.6	0.8
Total	100	100	100	100	100	100	100	100	100	100	99.4	99.2
total without pass 75	98.4	98.4	100	100	98.5	98.4	98.7	98.4	98.5	98.5	98.8	98.4

Laboratory Number	**88**	**88**	**96**	**96**	**101**	**101**	**152**	**152**	**183**	**183**	**188**	**188**
Sample Number	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**
Silicate (4.75-2.36 mm)	29.5	26.0	26.0	20.0	20.2	22.3	22.0	26.5	30.6	28.7	19.5	23.5
Silicate (2.36-1.18 mm)	41.0	37.5	33.5	30.0	35.2	30.9	25.5	36.0	34.7	37.7	31.5	25.0
Silicate (1.18-0.600 mm)	49.5	54.0	45.5	45.5	51.7	53.3	51.5	53.0	39.5	39.7	49.0	47.0
Silicate (0.600-0.300 mm)	70.5	69.0	64.0	65.0	66.0	69.1	72.0	73.5	47.0	46.4	54.0	68.0
Silicate (0.300-0.150 mm)	74.5	72.0	81.0	75.0	81.3	81.8	85.0	85.0	58.7	60.0	74.5	75.5
Silicate (0.150-0.075 mm)	75.5	76.0	83.0	80.5	88.4	89.1	91.5	90.0	59.9	60.7	83.0	80.0
Silicate (wt. avg. %)	**54.4**	**53.7**	**52.4**	**49.1**	**52.1**	**53.3**	**51.6**	**54.7**	**41.7**	**41.7**	**47.6**	**49.9**
Carbonate (4.75-2.36 mm)	64.5	68.0	71.5	76.5	78.4	76.1	68.0	59.5	65.05	67.1	78.0	76.0
Carbonate (2.36-1.18 mm)	51.0	55.5	63.0	67.0	63.9	67.6	67.0	51.5	62.2	59.3	65.0	74.5
Carbonate (1.18-0.600 mm)	46.0	43.5	50.5	50.5	48.0	46.7	43.5	41.0	56.5	55.8	51.0	52.0
Carbonate (0.600-0.300 mm)	23.5	26.0	33.5	33.0	32.5	29.2	25.0	23.5	50.8	50.8	45.0	30.5
Carbonate (0.300-0.150 mm)	17.5	18.0	15.5	23.0	16.4	15.3	12.5	11.0	35.5	35.1	23.0	22.0
Carbonate (0.150-0.075 mm)	11.5	14.0	13.0	13.0	8.7	9.1	5.0	6.0	22.8	22.7	13.0	14.5
Carbonate (wt. avg. %)	**39.1**	**40.5**	**44.3**	**47.8**	**46.6**	**45.3**	**42.9**	**37.6**	**54.0**	**53.9**	**50.6**	**48.7**
Shale (4.75-2.36 mm)			1.0		0.5	0.9			3.4	2.8		
Shale (2.36-1.18 mm)			2.0			0.9	0.5		2.7	2.2	0.5	
Shale (1.18-0.600 mm)			1.0						3.2	2.6		
Shale (0.600-0.300 mm)			0.5						1.5	1.6		
Shale (0.300-0.150 mm)									0.4			
Shale (0.150-0.075 mm)												
Shale (wt. avg. %)			**0.9**		**0.1**	**0.3**	**0.1**		**2.3**	**1.9**	**0.1**	
Mica (4.75-2.36 mm)												0.5
Mica (2.36-1.18 mm)												
Mica (1.18-0.600 mm)				0.5			0.5		0.8	1.5		0.5
Mica (0.600-0.300 mm)	3.5	2.5	0.5	1.5	1.5	1.7	1.0		0.8	1.2	1.0	1.5
Mica (0.300-0.150 mm)	8.0	9.0	3.5	1.5	2.3	2.9	2.5	3.5	5.4	4.9	2.5	2.5
Mica (0.150-0.075 mm)	13.0	10.0	4.0	6.0	2.9	2.0	3.5	4.0	17.4	16.7	4.0	5.0
Mica (wt. avg. %)	**2.4**	**2.2**	**0.8**	**0.9**	**0.8**	**0.9**	**0.8**	**0.5**	**1.7**	**1.9**	**0.7**	**1.1**
Chert (4.75-2.36 mm)	1.0	0.5	1.5	2.0			1.0				1.0	
Chert (2.36-1.18 mm)			1.5	3.0		0.2	0.5	0.5			1.5	0.5
Chert (1.18-0.600 mm)				3.5	0.3							
Chert (0.600-0.300 mm)												
Chert (0.300-0.150 mm)												
Chert (0.150-0.075 mm)												0.5
Chert (wt. avg. %)	**0.2**	**0.1**	**0.5**	**1.7**	**0.1**	**0.0**	**0.3**	**0.1**			**0.4**	**0.1**

Laboratory Number	**88**	**88**	**96**	**96**	**101**	**101**	**152**	**152**	**183**	**183**	**188**	**188**
Sample Number	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**	**1.14**	**2.14**
Cemented Particles (4.75-2.36 mm)	0.5	1.0		1.5	0.9			2.0	1.0	1.4	1.0	
Cemented Particles (2.36-1.18 mm)	1.0				0.9	0.6		2.0	0.4	0.9	1.5	
Cemented Particles (1.18-0.600 mm)										0.4		0.5
Cemented Particles (0.600-0.300 mm)												
Cemented Particles (0.300-0.150 mm)												
Cemented Particles (0.150-0.075 mm)												
Cemented Particles (wt. avg. %)	**0.3**	**0.2**			**0.3**	**0.1**		**0.8**	**0.3**	**0.5**	**0.4**	**0.1**
Conglomerate, sandstone, quartzite (4.75-2.36 mm)	4.5	4.5				0.7	9.0	12.0			0.5	
Conglomerate, sandstone, quartzite (2.36-1.18 mm)	7.0	7.0					6.5	10.0				
Conglomerate, sandstone, quartzite (1.18-0.600 mm)	4.5	2.5	3.0				4.5	6.0				
Conglomerate, sandstone, quartzite (0.600-0.300 mm)	2.5	2.5	1.5	0.5			2.0	3.0				
Conglomerate, sandstone, quartzite (0.300-0.150 mm)		1.0		0.5				0.5				
Conglomerate, sandstone, quartzite (0.150-0.075 mm)												
Conglomerate, sandstone, quartzite (wt. avg. %)	**3.7**	**3.3**	**1.1**	**0.2**		**0.1**	**4.4**	**6.3**			**0.1**	
Oxide Minerals (4.75-2.36 mm)												
Oxide Minerals (2.36-1.18 mm)												
Oxide Minerals (1.18-0.600 mm)												
Oxide Minerals (0.600-0.300 mm)												
Oxide Minerals (0.300-0.150 mm)												
Oxide Minerals (0.150-0.075 mm)												
Oxide Minerals **(wt. avg. %)**												
Gradation (% retained)												
(4.75-2.36 mm)	15.4	15.8	13.2	14.6	17.6	17.2	17.8	17	16.8	21.2	14.4	14.4
(2.36-1.18 mm)	18.8	18.2	17.5	18.2	17.9	17.7	19.3	20.5	19.8	18.4	17.6	19.1
(1.18-0.600 mm)	23.5	23	23.6	24.3	23.4	23.5	23.3	23.8	25.4	22.8	24.2	23.4
(0.600-0.300 mm)	26	26	27.6	26.8	23.4	23.5	24.6	24.6	22.6	21.7	27	26.1
(0.300-0.150 mm)	12.4	12.9	13.7	12.5	12.3	12.5	11.5	11	11.2	11.5	12.9	12.9
(0.150-0.075 mm)	3.9	4.1	4.4	3.6	4.1	4.4	3.5	3.1	3	3.1	3.9	4.1
pass 75 µm	0	0	0	0	1.3	1.2	0	0	1.2	1.3	0	0
Total	100	100	100	100	100	100	100	100	100	100	100	100
total without pass 75	100	100	100	100	98.7	98.8	100	100	98.8	98.7	100	100

Appendix F1: Production Laboratory Ratings

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-607 % Crushed Particles	LS-621 % Asphalt Coated	LS-608 % Flat & Elongated	Rating
2	9	24.3	9	10	9	88
4	3	25.4	8	8	10	78
8	10	28.6	9	10	10	97
9	10	19.4	10	9	6	78
12	9	26.2	10	10	10	93
13	10	28.4	10	9	10	96
15	10	28.9	10	10	8	96
16	6	25.6	9	0	10	72
17	10	21.8	4	4	9	70
18	8	29.7	10	10	10	97
19	10	26.2	5	10	10	87
20	10	29.5	10	10	10	99
21	8	28.1	3	3	10	74
22	10	28.6	10	10	10	98
23	10	28.1	9	0	9	80
25	10	24.5	9	10	10	91
26	9	24.8	9	9	8	85
27	10	28.1	10	10	10	97
28	0	26.7	10	10	10	81
29	5	22.1	9	10	8	77
30	8	19.4	9	10	10	81
31	5	26.2	6	10	6	76
32	9	24.0	9	6	7	79
33	10	29.5	10	10	10	99
34	10	28.4	10	10	8	95
35	10	29.2	9	10	10	97
36	6	26.5	9	10	7	84
37	8	27.8	10	10	7	90
38	10	24.0	9	10	10	90
39	10	21.3	10	10	9	86
42	10	28.1	10	1	4	76
43	9	26.7	0	10	9	78
44	10	25.1	9	10	10	92
45	9	28.4	6	10	7	86
46	9	29.5	7	8	10	91
47	9	23.5	8	10	9	85
52	5	26.2	10	5	10	80
54	5	28.1	10	10	9	89

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-607 % Crushed Particles	LS-621 % Asphalt Coated	LS-608 % Flat & Elongated	Rating
56	10	27.5	10	10	10	96
58	10	25.9	8	9	10	90
59	10	29.5	10	10	10	99
60	8	26.2	10	8	0	75
61	10	26.5	10	10	10	95
62	9	27.0	10	8	10	91
63	10	25.4	7	7	10	85
64	9	22.1	7	9	6	76
65	6	25.6	8	9	9	82
67	10	17.5	0	9	0	52
68	10	30.0	10	9	10	99
69	10	26.5	10	8	10	92
70	10	29.5	10	10	10	99
71	10	24.3	10	9	10	90
72	10	20.5	10	9	10	85
73	10	27.0	0	5	4	66
74	10	28.4	10	9	10	96
75	10	29.5	8	10	7	92
76	10	28.6	10	10	10	98
77	9	26.2	10	10	10	93
79	10	29.7	7	9	10	94
80	10	29.7	10	10	10	100
81	8	28.6	10	9	8	91
83	10	24.5	10	5	10	85
85	8	26.5	10	9	10	91
86	7	28.9	9	9	10	91
89	10	28.6	6	8	10	89
90	10	28.4	10	10	10	98
93	10	28.1	10	10	10	97
95	10	28.1	10	10	10	97
97	10	30.0	8	9	9	94
98	6	25.4	0	9	3	62
99	10	29.2	10	9	9	96
100	10	27.5	8	10	9	92
101	9	24.5	10	10	10	91
102	7	21.5	5	0	10	62
103	7	24.5	10	10	10	88
107	10	29.2	10	10	10	99
108	8	22.1	10	10	10	86
110	0	28.4	10	8	7	76
112	10	22.9	10	9	6	83
113	9	27.3	7	10	1	78
114	9	28.4	10	10	10	96

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-607 % Crushed Particles	LS-621 % Asphalt Coated	LS-608 % Flat & Elongated	Rating
116	8	23.5	10	2	8	74
117	8	24.8	9	10	10	88
118	8	22.9	10	9	10	86
119	7	25.6	7	10	7	81
120	10	27.5	10	8	10	94
121	10	29.2	10	10	9	97
122	6	27.5	9	10	7	85
124	10	25.1	10	10	8	90
126	8	29.5	10	10	10	96
127	6	26.7	8	10	10	87
128	9	28.1	10	10	10	96
129	9	18.8	10	10	10	83
137	6	15.8	10	10	8	71
138	8	25.1	10	10	10	90
139	10	25.1	10	10	10	93
140	0	29.2	10	8	10	82
141	10	29.7	8	10	10	97
143	10	27.8	10	10	10	97
144	8	18.0	9	10	9	77
145	10	19.4	10	9	10	83
146	9	29.2	2	10	6	80
147	10	28.6	9	10	4	88
149	7	26.5	5	7	6	74
150	8	30.0	10	10	10	97
151	3	25.9	10	8	7	77
154	7	30.0	10	10	10	96
156	5	24.3	5	10	8	75
157	9	27.0	10	9	10	93
158	9	29.5	10	6	5	85
159	9	27.0	10	6	10	89
160	10	28.1	10	9	10	96
161	8	29.7	10	9	10	95
163	8	29.5	9	10	0	81
164	10	29.2	8	10	10	96
167	10	25.1	10	8	4	82
168	10	27.8	8	10	9	93
169	10	28.9	10	9	10	97
170	2	22.6	7	4	3	55
171	3	23.7	8	10	4	70
172	10	26.5	9	6	10	88
175	10	29.5	10	10	10	99
176	9	27.5	10	10	9	94
177	9	20.2	10	9	10	83

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-607 % Crushed Particles	LS-621 % Asphalt Coated	LS-608 % Flat & Elongated	Rating
178	10	26.5	10	10	9	94
179	10	28.6	9	8	10	94
180	9	27.3	7	10	6	85
181	10	25.4	6	10	10	88
182	10	28.9	7	10	7	90
183	10	26.5	10	9	10	94
184	10	26.7	9	10	10	94
186	10	25.4	10	8	9	89
187	0	24.0	3	10	9	66
188	9	29.5	9	10	10	96
191	2	27.5	5	10	9	76
193	10	28.6	10	10	10	98
194	8	28.1	10	10	10	94
195	6	23.7	10	8	6	77
196	10	25.4	9	9	4	82
198	10	26.2	7	10	7	86
199	10	30.0	10	9	10	99
200	0	23.2	5	10	8	66
205	10	26.2	0	9	4	70
210	10	28.4	10	6	10	92
214	5	21.0	6	10	10	74
216	10	26.7	10	9	10	94
217	6	28.6	9	10	10	91
218	9	26.2	4	10	9	83
219	10	28.9	10	9	8	94
232	10	29.7	10	8	10	97
234	5	25.9	10	9	10	86
235	10	19.6	8	5	10	75
236	9	20.5	10	10	9	84
245	9	29.2	10	10	7	93
248	10	25.4	8	10	8	88
249	10	22.9	9	10	10	88
250	8	27.8	7	9	10	88
251	7	25.9	9	10	10	88
252	9	25.9	2	6	9	74
253	9	26.7	7	9	8	85
254	10	27.8	10	10	10	97
255	8	29.2	9	9	9	92
257	10	28.6	8	2	10	84
258	10	29.7	10	9	10	98
260	5	24.3	0	7	9	65
261	9	28.4	10	10	8	93
262	5	27.5	10	10	0	75

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-607 % Crushed Particles	LS-621 % Asphalt Coated	LS-608 % Flat & Elongated	Rating
263	8	23.7	9	5	8	77
264	10	27.8	10	5	8	87
266	6	20.7	10	10	9	80
268	6	21.8	6	9	10	75
269	2	27.3	4	10	9	75
271	10	26.5	2	7	10	79
272	10	29.2	8	10	10	96
274	4	24.3	7	5	10	72
275	8	25.4	9	0	10	75
276	8	28.4	8	8	9	88
277	10	29.2	10	3	8	86
278	5	25.1	10	10	9	84
279	4	27.5	9	7	10	82
280	9	22.1	6	10	10	82
282	9	29.2	10	7	7	89
284	10	28.4	10	1	1	72
285	9	26.5	9	10	8	89
287	9	26.7	9	10	10	92
288	3	21.0	0	8	9	59
290	9	27.0	8	10	10	91
291	2	15.3	10	10	10	68
293	10	30.0	10	10	8	97
294	10	27.3	10	10	10	96
296	9	24.3	10	10	8	88
297	10	26.5	10	10	10	95
300	10	25.4	10	10	10	93
301	10	24.8	10	10	10	93
302	10	26.7	7	10	9	90
303	9	28.1	10	8	10	93
305	10	24.3	9	10	9	89
307	10	24.0	9	10	8	87
308	9	28.6	8	10	10	94
309	10	29.5	10	10	9	98
310	7	29.7	10	10	10	95
311	10	22.1	9	10	10	87
312	10	27.0	9	10	10	94
313	10	30.0	10	10	8	97
314	10	22.4	0	6	0	55
315	10	25.4	6	10	10	88
316	4	30.0	10	9	10	90
318	10	28.1	0	10	7	79
320	10	24.0	0	5	10	70
321	9	21.3	10	8	8	80

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-607 % Crushed Particles	LS-621 % Asphalt Coated	LS-608 % Flat & Elongated	Rating
323	9	22.4	10	10	9	**86**
324	10	28.4	10	10	10	**98**
325	9	13.4	10	*10*	9	**73**
326	10	29.7	9	*10*	10	**98**
327	9	25.6	9	*8*	10	**88**
328	10	26.5	10	*10*	10	**95**
329	10	27.3	10	*3*	10	**86**
331	8	23.5	9	*4*	10	**78**
332	10	30.0	2	*0*	10	**74**
333	10	15.0	10	*6*	10	**73**
335	5	26.7	10	*10*	8	**85**
337	10	24.5	10	*3*	10	**82**
339	10	29.2	6	*8*	6	**85**
340	10	27.3	10	*10*	10	**96**

Appendix F2: Full Service Aggregate Laboratory Ratings

FULL SERVICE AGGREGATE LABORATORY RATINGS 2014

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-603 LAA	LS-604 BRD/ABS (CA)	LS-606 $MgSO_4$ (CA)	LS-607 % Crush	LS-621 % Asphalt	LS-608 % Flat & Elongated	LS-618 MDA (CA)	LS-614 F/T	LS-605 BRD/ABS (FA)	LS-623 One-Point Proctor	LS-619 MDA (FA)	Rating
8	10	28.6		10.0	10	9	10	10	10	10	9.5	9.0	10	**97**
13	10	28.4		10.0	5	10	9	10	9	7	9.5	10.0	8	**90**
15	10	28.9		10.0	10	10	10	8	10	8	6.0	10.0	9	**93**
18	8	29.7		10.0	10	10	10	10	9	8	10.0	10.0	8	**95**
19	10	26.2	10	9.0		5	10	10	9	10	10.0	9.0	10	**92**
22	10	28.6		9.5		10	10	10	10	9	10.0	10.0	8	**96**
23	10	28.1		9.0		9	0	9	10	10	10.0	5.7	10	**85**
27	10	28.1	10	9.0	10	10	10	10	10	4	10.0	10.0	10	**94**
28	0	26.7		7.5		10	10	10	6	10	6.0	9.3	10	**81**
31	5	26.2	10	9.5	9	6	10	6	10	0	10.0	8.0	7	**78**
35	10	29.2	10	9.5	10	9	10	10	10	9	10.0	7.0	10	**96**
37	8	27.8	10	10.0	8	10	10	7	10	10	7.5	9.0	10	**92**
38	10	24.0	6	9.5	10	9	10	10	9	9	10.0	4.3	0	**81**
39	10	21.3		4.5		10	10	9	7	10	10.0	10.0	6	**83**
47	9	23.5	10	10.0	7	8	10	9	7	10	6.5	9.0	10	**86**
56	10	27.5	10	10.0	9	10	10	10	10	6	9.0	9.0	10	**94**
59	10	29.5		8.0	10	10	10	10	10	10	9.5	10.0	10	**98**
61	10	26.5		7.0		10	10	10	9	8	7.5	7.7	9	**88**
69	10	26.5		7.5		10	8	10	10	10	10.0	9.7	10	**94**
75	10	29.5		8.5	8	8	10	7	10	10	10.0	10.0	10	**94**

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-603 LAA	LS-604 BRD/ABS (CA)	LS-606 $MgSO_4$ (CA)	LS-607 % Crush	LS-621 % Asphalt	LS-608 % Flat & Elongated	LS-618 MDA (CA)	LS-614 F/T	LS-605 BRD/ABS (FA)	LS-623 One-Point Proctor	LS-619 MDA (FA)	Rating
76	10	28.6		10.0	9	10	10	10	7	10	10.0		10	**96**
79	10	29.7		8.5		7	9	10	10	10	10.0	10.0	10	**96**
80	10	29.7	10	0.5	10	10	10	10	10	7	7.0	10.0	5	**86**
83	10	24.5		7.0	10	10	5	10	10	10	10.0	10.0	9	**90**
86	7	28.9		9.0		9	9	10	10	1	9.0	4.0	8	**81**
90	10	28.4		8.0	5	10	10	10	9		9.5		7	**89**
98	6	25.4		3.0	10	0	9	3	9	9	9.0	8.7	9	**72**
101	9	24.5		10.0	10	10	10	10	8	10	10.0	10.0	10	**94**
102	7	21.5		10.0		5	0	10	10	9	10.0	10.0	9	**78**
107	10	29.2		9.5	3	10	10	10	10	10	9.5		9	**92**
108	8	22.1		7.0	9	10	10	10	10		9.0	10.0	7	**86**
110	0	28.4		9.0	9	10	8	7	7	10	10.0	8.0	6	**80**
112	10	22.9		8.5	10	10	9	6	8	10	4.5	10.0	10	**85**
114	9	28.4		10.0	10	10	10	10	10	10	9.5	10.0	10	**98**
120	10	27.5		9.5		10	8	10	10	7	10.0	10.0	10	**94**
121	10	29.2		10.0	10	10	10	9	10	8	9.5	10.0	9	**96**
124	10	25.1		9.0		10	10	8	10	9	10.0	10.0	10	**93**
157	9	27.0		10.0	7	10	9	10	9	10	9.0		5	**88**
164	10	29.2		9.0	6	8	10	10	4	10	10.0		4	**85**
172	10	26.5		9.5	10	9	6	10	7	10	10.0	10.0	9	**91**
177	9	20.2		8.5		10	9	10	7	7	8.0		6	**79**
183	10	26.5		10.0	2	10	9	10	10	8	10.0	10.0	9	**89**
188	9	29.5	10	10.0	10	9	10	10	10	10	10.0	10.0	10	**98**
199	10	30.0		10.0		10	9	10	4	10	10.0	10.0	10	**95**
205	10	26.2		6.5		0	9	4	9	10	9.5	9.7	10	**80**
216	10	26.7		9.0	10	10	9	10	8	10	5.5	8.7	9	**90**
217	6	28.6		9.0	10	9	10	10	10		6.0		10	**91**
245	9	29.2		9.0		10	10	7	7	10	9.5	10.0	10	**93**
257	10	28.6		7.5	9	8	2	10	10	10	9.5	10.0	10	**89**

Lab No.	LS-601 Wash Pass	LS-602 Gradation	LS-603 LAA	LS-604 BRD/ABS (CA)	LS-606 $MgSO_4$ (CA)	LS-607 % Crush	LS-621 % Asphalt	LS-608 % Flat & Elongated	LS-618 MDA (CA)	LS-614 F/T	LS-605 BRD/ABS (FA)	LS-623 One-Point Proctor	LS-619 MDA (FA)	Rating
260	5	24.3		10.0	7	0	7	9	8	8	6.5	10.0	9	**74**
263	8	23.7		10.0	9	9	5	8	8	10	8.0	6.3	10	**82**
285	9	26.5		9.0	10	9	10	8	9	9	10.0	7.7	10	**91**
293	10	30.0		10.0	6	10	10	8	10	10	9.5	8.7	10	**94**
296	9	24.3		9.0		10	10	8	3	7	9.0	5.3	10	**80**
301	10	24.8		9.0	10	10	10	10	9	9	5.5	8.3	10	**90**
309	10	29.5		9.5	10	10	10	9	10	10	9.5	10.0	10	**98**
312	10	27.0		10.0	3	9	10	10	5	10	9.0	5.3	9	**84**
316	4	30.0		9.5	10	10	9	10	10	9	9.0	10.0	10	**93**
325	9	13.4		8.0		10	10	9	10	0	7.5	8.7	10	**73**
326	10	29.7		6.5		9	10	10	9	9	6.5	9.3	5	**88**

Appendix F3: Soil Laboratory Ratings

Lab No.	LS-702 Hydrometer Analysis	LS-703 & 4 Atterberg Limits	LS-705 Specific Gravity	Rating
8	8.6	9.0	10	92
9	10.0	9.7	5	82
12	5.4	8.0	6	65
13	8.6	9.7	10	94
15	10.0	10.0	10	100
18	10.0	10.0	10	100
19	8.8	9.3	10	94
20	8.8	10.0	10	96
21	10.0	9.0	7	87
22	9.8	10.0	10	99
23	8.4	9.3	9	89
27	9.6	8.3	9	90
28	10.0	10.0	10	100
29	9.2	10.0	10	97
30	8.0	9.3	10	91
31	6.4	10.0	10	88
32	3.2	7.7	10	70
35	8.0	8.7	10	89
37	9.4	9.3	10	96
38	7.6	2.3	7	56
44	9.8	5.0	10	83
46	9.0	9.3	10	94
47	9.4	7.3	10	89
52	3.6	8.0	0	39
54	9.4	7.7	8	84
56	0.0	10.0	0	33
58	9.6	9.7	10	98
59	9.4	10.0	10	98
62	9.4	9.7	10	97
63	4.2	10.0	9	77
64	9.8	9.3	8	90
68	8.2	9.3	10	92
69	10.0	10.0	10	100
71	7.8	9.0	5	73
72	9.8	8.0	10	93
74	9.4	7.7	6	77
79	9.4	10.0	10	98
80	9.6	10.0	10	99
81	7.8	10.0	10	93

Lab No.	LS-702 Hydrometer Analysis	LS-703 & 4 Atterberg Limits	LS-705 Specific Gravity	Rating
83	9.8	7.7	10	92
85	7.6	8.3	10	86
86	6.6	3.3	8	60
101	3.4	9.3	10	76
102	9.8	5.3	10	84
112	5.6	10.0	10	85
114	9.6	8.7	5	78
118	8.6	9.3	7	83
120	10.0	10.0	10	100
121	7.6	10.0	10	92
126	8.8	8.3	0	57
138	10.0	9.0	10	97
139	8.6	9.7	4	74
144	7.6	9.0	8	82
146	10.0	10.0	8	93
149	9.6	8.7	10	94
151	9.2	8.3	8	85
156	10.0	7.7	8	86
159	7.8	9.3	9	87
168	10.0	10.0	10	100
170	9.2	8.7	0	60
171	9.0	10.0	9	93
172	9.2	10.0	10	97
183	8.8	9.7	10	95
188	9.8	8.3	10	94
195	10.0	10.0	10	100
206	0.0	8.0	0	27
210	8.2	9.0	10	91
216	8.6	10.0	10	95
253	7.2	8.3	8	78
260	6.6	7.0	10	79
261	9.6	9.0	8	89
266	1.8	7.0	3	39
276	9.0	10.0	10	97
284	8.4	10.0	9	91
285	8.2	10.0	8	87
287	8.8	7.7	8	82
296	9.8	10.0	10	99
300	9.0	8.3	10	91

301	7.6	10.0	10	**92**
307	9.8	9.7	10	**98**
312	9.2	10.0	10	**97**
315	5.0	7.7	0	**42**
320	8.2	8.3	8	**82**

322	0.0	7.0	6	**43**
326	10.0	10.0	10	**100**
332	9.8	7.7	10	**92**
333	9.8	10.0	10	**99**

Appendix F4: Superpave Laboratory Ratings

Laboratory No.	C1252/T 304 Uncompacted Void Content	D2419/T 176 Sand Equivalent	ASTM D5821 % Fractured Particles	ASTM D4719 % Flat & Elongated	Rating
13	10	9	10	8	93
15	9	6	10	9	85
18	10	10	9	8	93
19	9	0	7	9	63
20	0	10	10	10	75
21	8	6	10	10	85
22	7	10	10	9	90
25	10	10	10	10	100
26	10	10	7	9	90
27	10	10	10	10	100
28	9	7	10	9	88
31	6	10	10	6	80
33	10	10	10	10	100
35	9	10	10	10	98
37	8	10	10	10	95
39	10	10	8	2	75
43	10	10	9	8	93
47	6	10	10	10	90
56	9	10	10	8	93
58	4	10	7	10	78
59	10	3	10	10	83
61	9	10	10	10	98
62	10	10	9	10	98
69	10	10	3	7	75
71	10	7	9	9	88
75	10	3	7	9	73
77	10	9	10	10	98
79	10	10	2	9	78
80	10	10	10	6	90
86	10	9	0	10	73
101	10	0	10	10	75
108	7	5	9	4	63
112	9	10	8	6	83
114	9	8	5	10	80
120	0	10	9	5	60
121	10	10	7	10	93

Laboratory No.	C1252/T 304 Uncompacted Void Content	D2419/T 176 Sand Equivalent	ASTM D5821 % Fractured Particles	ASTM D4719 % Flat & Elongated	Rating
124	9	8	10	10	93
157	10	10	6	8	85
172	10	10	7	10	93
183	10	7	9	10	90
188	10	10	10	10	100
193	10	9	9	10	95
199	9	10	8	9	90
216	10	10	10	10	100
217	4	5	10	10	73
245	10	10	10	10	100
253	7	5	10	10	80
255	9	10	8	8	88
257	7	5	8	6	65
263	10	10	10	7	93
271	10	10	7	10	93
285	8	9	10	10	93
293	7	10	10	7	85
296	10	10	10	10	100
300	9	9	9	10	93
312	10	10	10	10	100
316	9	10	10	10	98
325	9	9	5	9	80
326	10	10	10	10	100
340	9	10	9	10	95